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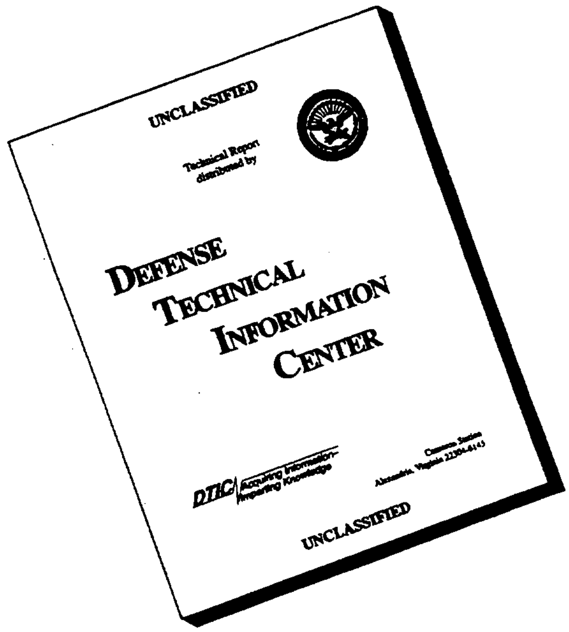

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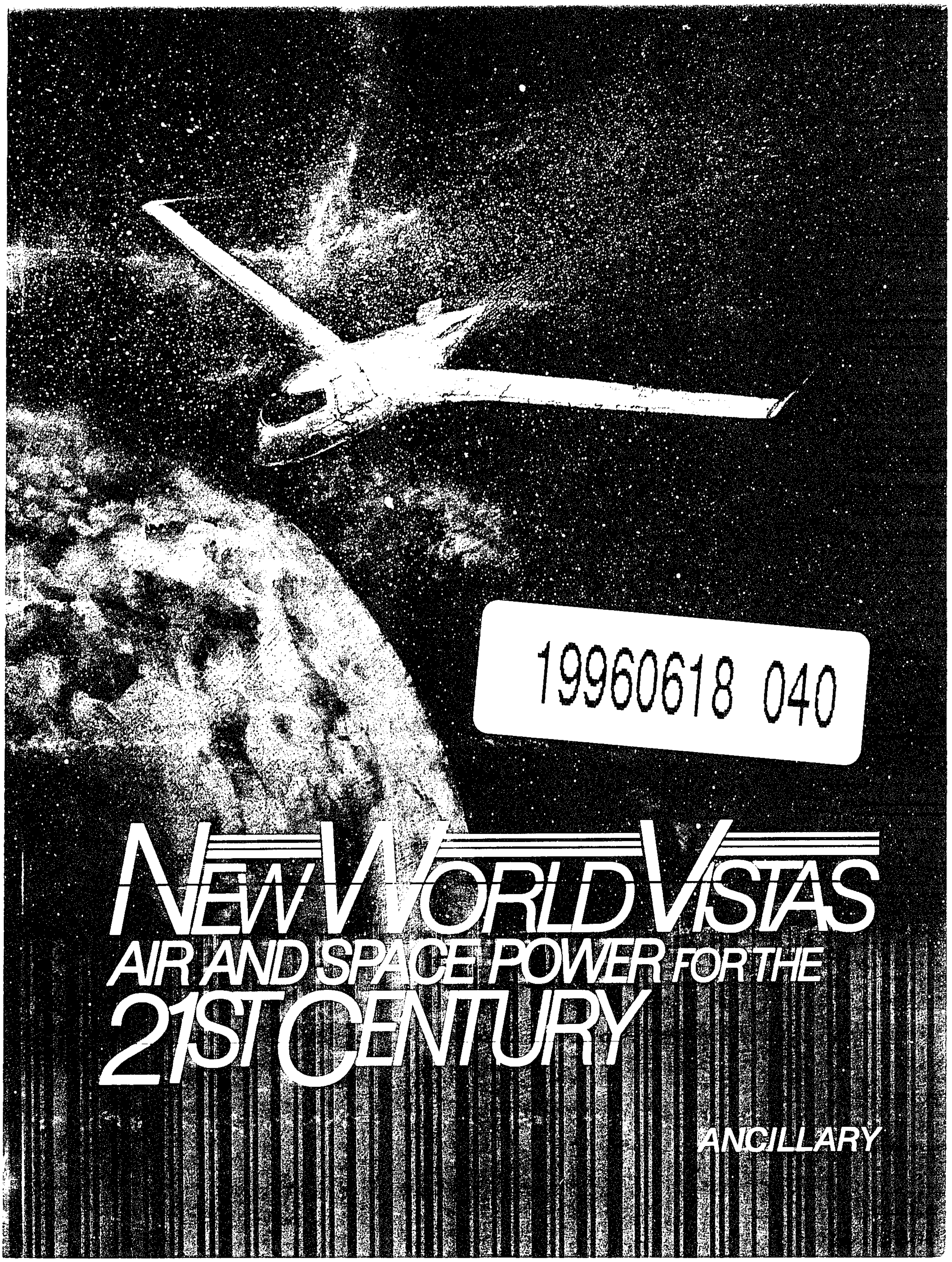
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NEW WORLD VISTAS
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ANCILLARY VOLUME

This report is a forecast of a potential future for the Air Force. This forecast does not necessarily imply future officially sanctioned programs, planning or policy.

Foreword

New World Vistas was a major undertaking for the USAF Scientific Advisory Board (SAB). Many people participated and made important contributions to the 14 other Volumes of this study. As the other 14 Volumes were being completed it became clear that some of the work was going to fall on the editing room floor. While many of the ideas were captured in the other Volumes, the specific work was not. The purpose of this 15th Ancillary Volume is to capture these significant contributions which otherwise would be lost.

What follows is in three basic parts. First are the proceedings of the Fiftieth Anniversary Symposium of the USAF Scientific Advisory Board held on November 10, 1994. Next are the papers requested by the Chairman of the SAB, Dr. Gene McCall, for members of the SAB to forecast possible developments over the next 50 years. Finally, a series of interviews with distinguished Americans who provide their insights into the future.

This Ancillary Volume, along with the 14 others, completes the body of work by the SAB on *New World Vistas.*

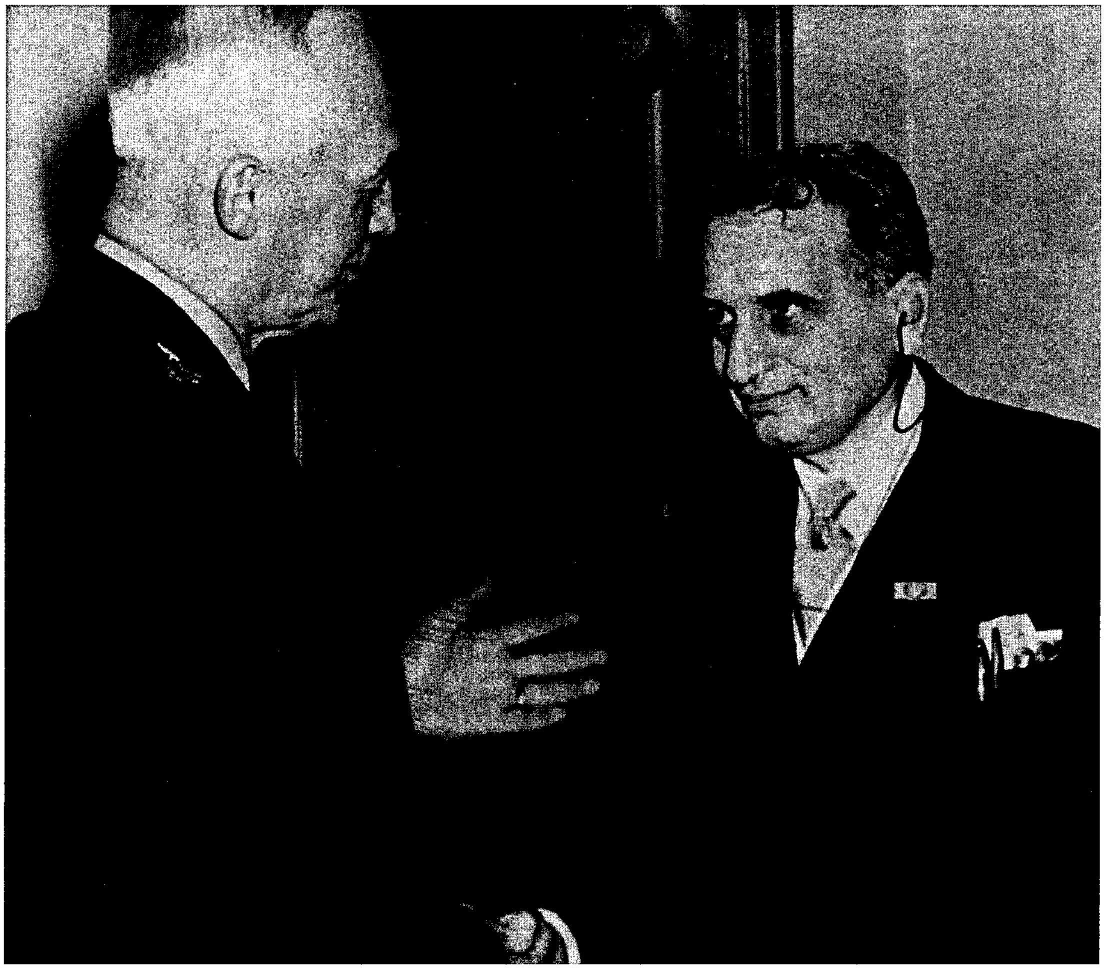

Figure 1. Five Star General Hap Arnold thanks Dr. Theodore von Kármán following the completion of the first Airpower S&T report. The report, Toward New Horizons, was submitted on 15 December 1945.

Figure 2. Secretary of the Air Force, Dr. Sheila Widnall, and Air Force Chief of Staff, General Ronald Fogleman, formally issue the challenge to Dr. Gene McCall on 10 November 1994.

Figure 3. Dr. Gene McCall accepts the New World Vistas challenge, 10 November 1994.

Figure 4. General Ronald Fogleman and Dr. Sheila Widnall accept the Summary Volume of New World Vistas *from Dr. Gene McCall, 15 December 1995, exactly 50 years after Kármán's report was filed. The decorations were part of the "Secretary's Christmas Party" festivities.*

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Introduction

General "Hap" Arnold formally established the Scientific Advisory Group (SAG) in a memorandum to Dr. Theodore von Kármán on November 7, 1944. This group produced the futuristic study, *Toward New Horizons*, which set forth many of the early research and development goals pursued by the Air Force. Its importance is still felt in the Air Force forecasting process. The SAG evolved into a permanent body in June 1946, as the Scientific Advisory Board (SAB) that exists today.

The purpose of the 50th Anniversary Symposium was to assess the contributions, processes, and problems associated with the independent advisory functions of the SAB with the goal of determining the proper role of independent advisory committees in the future, given the current restructuring of the industrial base, the changing nature of current national threats, and the new world political situation.

These are the transcribed speeches originally presented at the 50th Anniversary Symposium of the SAB held at the National Academy of Sciences (NAS) on November 10, 1994. The symposium was composed of four panels. The participants were charged to provide historical insight into the creation and growth of the SAB during different periods of its development.

The formidable task of organizing these transcriptions was tackled by Major Barbara Luke (USAFR). We hope that these talks, given by the individuals who were actually involved in the events, will serve as a vital source of knowledge for those future generations who choose to study the history of science, technology, and the USAF.

Opening Remarks

Dr. Gene McCall, Chairman of the Scientific Advisory Board

The 50th Anniversary meeting of the Scientific Advisory Board is certainly about science, but it's also about history. In the Offices of the Secretary of the Air Force and the Chief of Staff, we have both of those disciplines represented.

This morning it's with great pleasure that I first introduce General Ronald Fogleman, the new Air Force Chief of Staff, who taught history at the Air Force Academy for two and a half years. General Fogleman is well known to many of us as the former Commander in Chief of TRANSCOM, Commander of Air Mobility Command. He, early in his career, instructed student pilots. He was a combat pilot and fighter pilot and high speed forward air controller in Vietnam and Thailand. He also engaged in duty as an F-15 aircraft demonstration pilot for numerous international air shows.

Over the past decade he has commanded an Air Force Wing, Air Division, directed Air Force programs at the Pentagon, and served as commander 7th Air Force before coming to Scott as CINCTRANSCOM. It is with great pleasure that I introduce General Fogleman, Air Force Chief of Staff.

Not a "Dumb Coach"

General Ronald R. Fogleman, Chief of Staff, USAF

It's great to see everyone this morning and to help officially kick off this very special 50th Anniversary Symposium of the Scientific Advisory Board.

Last night I reflected on the history of the Scientific Advisory Board in my remarks, and this morning I'd like to just very briefly share my philosophy on the role that the Board will play on the Air Force team that we are so proud of.

From my perspective, the Board has been a very strong and powerful voice within the Air Force. We have just been reminded that over the last 50 years you've lived up to the reputation and the goals that Dr. Theodore von Kármán established, to think boldly about technical promise of air and space power. You provided a link between the operator, their problems, and future technical solutions. Dr. McCall just mentioned three dimensions of that in terms of helping us solve near term technical problems as well as working the mid-term imperatives for the operators. And as Lt.Gen. Dick Hawley pointed out, "Somebody's got to sit back and look out into the far future with the vision and the understanding of how to apply technology."

Certainly, close operator and scientific communities ties are as important today as they were when Hap Arnold and Dr. von Kármán got together. We need scientific visionaries who can look into the future and advise the Chief of Staff and other senior Air Force leaders about technologies which might be relevant 15 or 20 years from now. We need great minds to help us ensure our potential combat capabilities and allow us to be an effective player on the joint team. In today's era of tight budgets, we cannot afford to invest billions of dollars on systems that will be obsolete or non-effective on the battlefield. Former Chief, General Lew Allen, has said that not all new ideas are necessarily good ideas. We need the SAB to sort through the wheat and the chaff and keep us focused as we invest these scarce dollars.

Your study topics for the next year show that you are looking to the future and that you see it as one of opportunities, not problems. These subjects reflect some of the toughest challenges facing our joint warfighters. Issues like how to attack deep hardened targets; how to better integrate our space-based forces to support the warfighter; how to refine the concept of boost-phase intercept technologies? These are of great importance not only to the Air Force but to the nation. You're on the right path for tackling subjects that are important and will keep the Board focused on the operator.

I know General Hap Arnold had immense respect for his counterpart on this Board. I have that same respect for Dr. Gene McCall. I know that Gene and I will continue to build the kind of close personal and professional relationship that Arnold and Kármán shared, because it is crucial to success.

There's a story about a football team that highlights the importance of the relationship between the Board and the senior Air Force leadership. It seems like one Sunday this pro football team had to put in its backup quarterback late in the game. Now the team was ahead, but barely ahead, and they were really just hanging on. All this quarterback had to do was avoid making a big mistake, and they would win the game.

Now this guy was untested, and the coach wasn't really sure whether he could pull this off, so the coach instructed the quarterback very carefully. He said, "Let the halfback run the ball three times, and then punt."

The halfback ran the first time, 20 yard gain. The second time, he made a 30 yard gain. Runs the third time, 40 yard gain. So after three plays, the team is on the one yard line. The crowd's going wild. Another score is going to seal the victory, taking it out of range. The fourth play, the quarterback steps back and punts the ball. Stunned silence.

The quarterback headed to the sidelines. The coach was irate. He asked, "What were you thinking out there?" The quarterback replied, "I was thinking that since you didn't change the plan I had to have the dumbest coach in the business." (Laughter)

The fact is that we need great minds to not only describe what the potential for air and space power offers, but also to make sure that we don't allow our current planning to get outdated. Based on your track record, we can count on the Scientific Advisory Board to provide this type of independent and innovative thinking. I believe that open communications between my office and the Scientific Advisory Board will help us toward this objective. You are all part of a great legacy, and I know you will live up to your reputation. I want to thank you, and extend my best wishes for both a successful and an enjoyable symposium.

The Challenge

Dr. Sheila E. Widnall, Secretary of the Air Force

I can't tell you how excited I am to be here today to set the stage for discussing five decades of progress toward new horizons. We're here, of course, because fifty years ago General Hap Arnold and Dr. Theodore von Kármán shared a unique vision—the importance of independent scientific advice to the Air Force. This led to the establishment of the Scientific Advisory Board. It's clear that we wouldn't be in this room today if it were not for that vision. I'd like to reminisce about the legacy of the past, and issue a new challenge for the future SAB.

General Arnold and Dr. von Kármán made a superb team. Together they laid the groundwork for a unique relationship between the military and the world of science. Arnold was not a technical man, but he had a gift for anticipating the future. He recognized the importance of science and technology to achieving his objectives. In the closing months of World War II, he anticipated the need to build and maintain the world's most respected Air Force. General Arnold also had the uncanny ability to get people interested in his projects and to channel their efforts towards his goals. Lucky for us, on an autumn day in 1944, he was able to interest Dr. Theodore von Kármán in mapping out the future of the Air Force.

Dr. von Kármán was also a truly unique individual. He understood only the rudiments of military affairs, but grasped clearly which aspects of science would be of most use to the future Air Force. He combined the fundamentals of science with the pragmatism of engineering. Together, these two pioneers laid the intellectual framework for modern American airpower and strategic deterrence theory. We chose November 1994, for our celebration because it was this month, fifty years ago, that General Arnold asked Theodore von Kármán to search the world for the most advanced aeronautical ideas, and project them into the future. Arnold asked Kármán to use WW II only as a baseline for understanding existing aeronautical science, but in all other respects, "to divorce yourself from the present war."

In his challenge to Kármán, Arnold laid out several axioms that he believed were fundamental in developing a long term Air Force. First, that the United States was one of the predominant powers. Second, that our country would not support a large standing Army. And third, that it was a fundamental principle of American democracy that personnel casualties are and always will be distasteful. We will continue to fight mechanical rather than manpower wars.

Arnold's axioms are as valid today as they were a half century ago. The United States is the predominant power on the planet and, as the defense budgets continue to wind down, we're not able to sustain a large standing Air Force. Likewise, Desert Storm set a tough standard for low numbers in both casualties and duration.

Roughly one year after Arnold's challenge, Kármán's team responded with what has become a premier technological forecast, *Toward New Horizons*. In *Toward New Horizons,* Kármán concluded that among its future tasks the Air Force would have to "reach and hit targets swiftly and with great power, secure air superiority, and transport large forces of men and arms swiftly to any point on the globe." Does this sound like Global Reach/Global Power?

The foresight of *Toward New Horizons* was incredible. Truly a Declaration of Independence for the Air Force. Included in Kármán's predictions (and remember, this was 1945) were the advent of supersonic aircraft, pilotless aircraft, all weather flying, perfected navigation and communications, and aerial transportation of entire armies. But perhaps more valuable than any of the high profile aircraft or weapon systems he envisioned, Kármán also reminded us that only a "constant, inquisitive attitude towards science and a ceaseless and swift adaptation to new developments can maintain the security of this nation."

This reminder is perhaps more relevant today than it was fifty years ago. There has never been a period in the history of our country when "swift adaptations to new developments" was more important. One need only look at the blistering pace of computer technology and information system development to understand how the security of our nation depends on a constant inquisitive attitude.

I want to set a challenge for the SAB. As we celebrate the legacy of General Arnold and Dr. von Kármán, General Fogleman and I would like you to look toward the promises of the future. We want you to rekindle that constant inquisitive attitude towards science. So today, on this fiftieth anniversary of Arnold's challenge to Kármán, I would like to issue a challenge to today's Air Force Scientific Advisory Board. I challenge you, once again, to search the world for the most advanced aerospace ideas and project them into the future. Fifty years ago the SAB stepped up to the challenge of looking toward new horizons. Today, let's begin the search for *New World Vistas.*

The "New World" shows that we recognize the dramatic changes in the world, as well as in the Air Force. "Vistas" illustrates that we're standing on an overlook with a panoramic view of tomorrow.

Let me stress to you that this is not another Air Force internal requirement scrub to justify the Air Force science budget. Rather, it should be a truly independent futuristic view of how the exponential rate of technology change will shape the 21th Century Air Force. I'd like to begin this effort immediately, and complete the forecast within one year. My goal for you is that you should publish *New World Vistas* in December of 1995, on the fiftieth anniversary of the publication of *Toward New Horizons.*

I want to focus *New World Vistas* on three themes. First, to identify the fields of explosive technological change and assess their impact on the modern Air Force. Second, to identify the contributions of these changes to affordability of Air Force weapon systems and operations. And third, to identify areas and mechanisms for commercial cooperation.

Let me expand a bit on these three themes. Our Chief Scientist, Dr. Ed Feigenbaum, refers to this explosive technology change as "ultra rapid." For example, in the past the computer processor power per dollar ratio had doubled every three years. Today, it doubles every 12 to 18 months. The cost of magnetic disk computer memory has also been falling since 1990 at the rate of 70 percent per year. My challenge to you is to identify those areas which will likely revolutionize the 21st Century Air Force.

Several of these explosive changes may allow us to drastically reduce costs. I have personally witnessed the dramatic impact of computer aided design software and high speed

graphics on engineering costs. A recent MIT study found that corporate investments in information technology have been paying back a remarkably large return on investment. My challenge to you is to discover how technology can improve weapon system affordability and the overall economic efficiency of the Air Force.

Finally, I challenge you to identify areas that we can rely on or partner with the commercial world for technology development. Let us identify the areas where we are not the innovator but a very large, high-tech customer. Along the way you may identify opportunities for dual use, candidates for defense conversion, and suggestions for how we can become a better customer. After completion of this forecast, I would also like your thoughts on whether our current R&D infrastructure and the SAB organization is consistent with *New World Vistas.*

I know that several of you in the audience have been with the SAB from the beginning. You, now doubt, recall that roughly every ten years the Air Force has launched a major Science and Technology (S&T) forecast. These have shaped our S&T investments. You probably remember *Toward New Horizons*, *New Horizons II*, and *Project Forecast I and II.* Some of these have been more successful than others. The relative success of such forecasts seemed to depend on the degree of interaction with, and the commitment of senior Air Force leadership to enact the recommendations included in each report. If the success of *New World Vistas* depends on senior leadership commitment, then this is going to be a highly successful effort because General Fogleman, Dr. Feigenbaum, and I are fully committed to *New World Vistas.*

During last month's Corona Conference, Lieutenant General Joe Ralston discussed his work in revolutionizing the Air Force planning process. He plans to tap into the expertise at Air University. We want to integrate the SAB's *New World Vistas* forecast with this planning process.

Also last month, John Deutch unveiled a new DoD S&T strategy. The overall goal of this strategy is to maintain the technological superiority of the United States. The Air Force is going to be out front in trying to fulfill this goal. Like General Arnold, I believe it is axiomatic that superior science and technology will limit our personnel casualties and allow us to fulfill our mission with a smaller standing Air Force.

Today I've talked about the legacy of the past and issued a challenge for the future. The forward-looking posture of searching for *New World Vistas* is vital to the security of this nation. A fundamental part of Air Force culture is our high tech orientation. In the face of ultra-rapid change, the Air Force must take bold steps.

If General Arnold were here today, I'm sure that he would say, "Forget the past, forget the present. Project yourselves 10 or 20 years into the future." Help us to maintain the world's most respected air and space force. The future of our country depends on you.

Accepting the Challenge

Dr. Gene McCall

Dr. Widnall, I think you know from your association with the scientific community that a challenge such as yours is something that we all yearn for. I think we will produce for you a study and a search for new technologies that will certainly help the Air Force, and I think we'll enjoy doing it.

Thank you, for your charge.

We have heard many times over the past few years that the world is changing, that there is a new world, and I believe we all feel that we exist at a unique moment in time. There is something else which is unique at this point in history, and that is the technical orientation of the senior leadership of the Department of Defense. I can't remember, certainly not in recent years, a time in which there were so many technically adept people at the top of the Department. It's a great pleasure today to have as our keynote speaker, the leader of the technical group in this Department of Defense, Secretary William Perry.

Dr. Perry has a Ph.D. in Mathematics. I think most of you here are familiar with his technical accomplishments in the Department of Defense and the civilian world. We thank you very much for coming and taking the time to give the keynote address.

Keynote Address

Dr. William J. Perry, Secretary of Defense

Forty years ago in a speech at Columbia University Robert Oppenheimer said, "Both the man of science and the man of action live always at the edge of mystery, surrounded by it." We are men and women of science, and our work has served to strengthen America's armed forces—the men and women of action. Together, through technology, we have cut through the fog of war, the mystery that surrounds us.

I have been identified as a man of science for most of my career. More recently, some people have called me the "father of stealth technology," and Gen. Tony McPeak never lets me forget that. Every time it comes up he says, "If you're the father of stealth technology, when are you going to start making the child support payments?" (Laughter)

That's classic McPeak.

While I am a man of science, as the Secretary of Defense I recognize that science and defense technology alone will not ensure strong forces. The weapons are only as good as the troops that use them. I cannot lose sight of the importance of the individual in uniform. Therefore, my most important task since the day I was sworn in has been to maintain the high quality, the morale, and the capability of the people in uniform. I have inherited quality forces, high morale, high capability, and I have a responsibility to pass that same high quality force onto my successor.

The need to balance technology and people is particularly crucial as we face the unique challenges of the post Cold War era. As we peer into the future to see how science and technology can help us to deal with these challenges, we need to be very clear about the nature of the threats, and under what conditions we will respond to those threats with military force. We need to know how we will use our forces in order to determine how science and technology can best support them. I want to talk about a subject which is very important to me. It's right at the top of the issues which I think about every day. That is, how we decide where, when, and how to use military force.

Two thousand years ago the Roman poet Horace wrote, "Force without wisdom falls of its own weight." In the past two months, the United States has deployed its armed forces in two major contingency operations—one in Haiti and the other in the Persian Gulf. We were successful in both of those cases. The point I want to make today is that we were successful because of a combination of strong forces, strong will, quick response, and above all, a rational, pragmatic approach in deciding when and how to use force. In short, what Horace called "wisdom."

We live in an ad hoc world, but our decisions about the use of military force cannot and will not be ad hoc.

In discussing the use of force I start with a fundamental fact, that is; the United States is and will remain a global power. We have global interests because of our historical ties throughout the world, and because of the importance of the international economy to our own prosperity. Protecting these interests requires us to have security commitments around the globe.

The second fact in considering the use of force is that most of the current and foreseeable threats to the United States do not jeopardize our survival as a nation. Contrast this to World War II or the Cold War.

In World War II, we faced totalitarian states bent on world domination. It was easy to decide our objectives, it was easy to decide how to use military force. Our objective was total victory, and we used every force available to us to achieve that. No hesitation, no agonizing decisions, we used it all.

In the Cold War we face an ideologically driven nuclear super power—hostile to democratic states. Our objective then was also easy to state—deter an attack from the forces of the Soviet Union and prevent a nuclear holocaust. All of the resources that were available to us were bent to that purpose.

Today the problems we face are very different and in many ways more complex. The Soviet Union, which dominated almost every element of America's security strategy, is now gone. In its place new nations have been born all over the Eurasian continent. All of them are struggling—struggling to become democracies, struggling to develop market economies, struggling to develop multi-ethnic societies. Indeed, across the globe, ethnicity (which Senator Moynihan once called the "great hidden force" of this age) is no longer hidden. It rips old states apart and causes the sometimes violent birth of new states. In short, these past few years have changed the security equation around the world, and required new thinking about the use of U.S. military power.

In approaching the problem, we have to begin with a basic understanding of the national interests of the United States. I find it convenient to think of these national interests in three different categories. First are vital national interests; second is where national interests are at stake that are not vital; and third are humanitarian concerns. I want to talk briefly about each of those three, because how we decide to use military force and what military force we decide to use depends on which of those three categories we consider our interests affecting.

A threat falls into the first category, that is vital national security interests, if it affects the survival of the United States or a key ally; if it threatens critical U.S. economic interests; or if it poses a future nuclear threat. Those are the three cases in which we consider that a threat infringes upon a vital national security interest. If we face such a threat, we must be prepared to use military force to end that threat. That means we must be prepared to risk a military conflict to protect our vital interests.

If we look back in recent history, there have been two recent confrontations which affected our vital national interests. One with Iraq and with North Korea. Both of those involve all three of these interests—a threat to key allies, a threat to critical economic interests, and a future nuclear danger. Let me talk about each of these situations in turn.

Seventeen months ago, North Korea threatened to withdraw from the Nuclear Non-Proliferation Treaty, and their pursuit of a nuclear weapon program coupled with a forward deployed million man army and a very bellicose posture created what we considered to be a very dangerous situation on the Korean Peninsula. To deal with this issue we began seventeen months ago what I would call preventive diplomacy. We had a long series of talks with North Korea.

In June those talks broke off when North Korea began unloading nuclear fuel from its reactor. They were taking the situation into their own hands, taking actions which made our negotiations pointless. So we broke off at that point. We concluded that our diplomacy had failed. At that point we shifted our strategy from preventive diplomacy to what I will call "coercive diplomacy" and began two actions simultaneously. One was imposing sanctions on North Korea; and second was augmenting the military forces which were then deployed in South Korea.

We clearly understood that these actions increased the risk of conflict, but we believed that it was even more dangerous to allow North Korea to proceed with a large scale nuclear weapons program. There were no risk-free solutions. We had to compare one course of action which had an immediate risk, with another course of action which had a more dangerous risk downstream.

The very day we were ready to request the sanctions and authorize the augmented military forces, the North Koreans told President Carter that they were ready to reopen negotiations aimed at terminating their nuclear weapon program. Indeed, those negotiations began and led to the so-called "Framework Agreement" which was signed in Geneva a few weeks ago.

The agreement that Ambassador Gallucci signed with the North Koreans, is a good deal for the United States and is a good deal for world security. It freezes immediately the North Korean nuclear weapons program and provides for the eventual dismantlement of all of its major facilities. This takes North Korea well beyond any commitments that it had made or would have made under the nuclear non-proliferation treaty.

Oliver Cromwell once said, "The best ambassador is a man of war." I like that phrase, but it's not quite true. Indeed, as the negotiations with North Korea proved, the best approach is a good ambassador *backed* by a man of war. In this case, backed by the threat of military force and backed by the threat of sanctions. This is what I would call using force deployed with wisdom.

Our response to Iraq's recent moves in the Persian Gulf also illustrates the importance of backing up our diplomacy with military forces. On October 8, 1994, we had firm intelligence that Saddam Hussein was moving Republican Guard forces to the border of Kuwait in a deployment very similar to the deployment he had made in August of 1990. Two days later, October 10, we had our first armored units in the desert in Kuwait at the Kuwaiti/Iraqi border. We had doubled the size of our air forces in Saudi Arabia, and we had moved a carrier battle group and a marine amphibious group into battle position.

This was an outstanding example of coercive diplomacy. We were prepared to fight a war, if necessary, but the rapid dispatch of forces to the Persian Gulf deterred Saddam Hussein, and therefore helped avoid that war. Again, I would call it force, deployed with wisdom.

While Iraq and North Korea fall into the first category, threats to our vital national interests, Haiti and Bosnia fall into a different category. A second category in which our vital interests are not threatened, but we do have interests, and we do have an important stake in the outcome. These cases are much more difficult to deal with than the first category, because we must weigh the risks involved against the interests involved against threats which are not always clear-cut. We tried a diplomatic solution, that was unsuccessful. After we believed we had truly exhausted all other alternatives, then the United States committed to use force to remove the military regime from power.

In Haiti, the threat to use this force turned out to be sufficient. This coercive diplomacy convinced the military regime to sign the agreement, to step down, and turn control over to the legal government. In this case we not only threatened the use of military power, we were actually in the process of applying it when the final agreement was reached. We actually had sixty aircraft in the air flying to Haiti, loaded with paratroopers, when the final agreement was reached. Fortunately, our communications were good enough to turn them back at that point.

Because of our demonstrated resolve to use military power, our armed forces entered Haiti without the loss of a single Haitian or American life. Just as importantly, we arrived there as friends instead of invaders, and that has had an enormous difference in the smoothness with which the operations have gone since then.

Let me contrast that with Bosnia. There, it is the best judgment of our military leaders that in order to impose the outcome we want, in order to force peace, it would take hundreds of thousands of troops and probably significant casualties. So while we want peace in that country, we are not willing to put out that level of blood and treasure to achieve that interest. That is not to say we don't have national interests in Bosnia. We do. We have important interests in preventing the war and its consequences from spreading beyond Bosnia. We also have a humanitarian interest in trying to limit the violence and relieve suffering while we work for a peace settlement. These are real interests, and we take them seriously. But they are limited interests, and our actions must be proportional to those interests. Those interests do not justify an action of sending several hundred thousand ground troops into Bosnia, and we have decided not to do it for that reason. That does not mean we have to wash our hands. The military still can help to achieve these limited objectives, but we are not prepared to enter the war as a combatant in order to achieve those objectives. So we're using selective military power for limited interests.

To keep the conflict from spreading, we deployed an infantry unit to Macedonia as part of a United Nations peacekeeping force, and to limit the violence, we are participating with other NATO countries with a substantial air force whose job it is to prevent aerial and artillery bombardment of Bosnian cities. Finally, we are supplying airlift and air drop to deal with humanitarian interests in that country.

NATO's commitment and the U.S. commitment has made a real difference. In the year before the decision to use NATO military power, more than 10,000 people died in Sarajevo alone as a result of military shelling. In the year since then, the number has measured in the dozens, not in the thousands. We have not brought about peace in Bosnia, so we cannot be satisfied with the results, but we have significantly limited the violence. Those are two examples of the use of force in the second category, where we have less than vital national interests at stake.

The third category I described is where our interests are humanitarian only. Here, we are using military forces but we are not using military force. That was the sole objective for our operation in Rwanda. Generally speaking, the military is not the right tool for dealing with humanitarian problems. The U.S. Government and the United Nations have both established ongoing programs to assist international and non-governmental agencies in providing humanitarian relief. Ordinarily the Defense Department is not involved in humanitarian operations. We focus on warfighting missions. In short, our job is to field an army, not a salvation army.

But under certain conditions, the use of our armed forces is appropriate. I want to spell out what those conditions are, because we are confronted with requirements, requests for the use of military forces, every week and we have to have some understanding of when we can apply them and when we should not.

First, we should participate if we face a natural or a man-made catastrophe that dwarfs the ability of the normal relief agencies to respond. In Rwanda, for example, the catastrophe was of biblical proportions with rampant cholera caused by a lack of potable water. Second, we should participate if the need for relief is urgent and only the military can jump start the effort. In Rwanda, there were literally 5,000 people a day dying of cholera in the camps, and the death toll was rising when we made the decision to go in and fix that problem. Third, we should participate if the response requires resources unique to the military. Again, in the case of Rwanda, only the United States military had the combination of water purification equipment, airlift, and engineering skills to make a quick difference, and we did. Within three days after the President's decision to assist in Rwanda, we had stopped the cholera epidemic and we had turned around the deaths that had measured in the thousands down to deaths measured in the dozens.

The final criteria which I look at very carefully is whether the operation involves intolerable risks to the American servicemen who are going to be participating in the operation. In Rwanda there was minimal risk to our troops; but even with that, we sent along with the engineers, with the people running the water purification equipment, we sent along some combat forces whose job it was not to fight a war, not to get involved in a civil war in Rwanda, but to protect our own forces and the lives of those people who were working with us.

So Rwanda met those tests, and the Defense Department brought its unique capabilities to bear on the crisis and we made a difference in a matter of a few days. We stopped the dying, we saved tens of thousands of lives, then we turned the effort over to the relief agencies and came back home. As I stand here today, we have no soldiers, airmen, marines, or sailors in Rwanda.

Those are the basic categories where we will use our armed forces. The bottom line is that we should not shrink from the use of military force when it's appropriate; but on the other hand, we should not rattle our saber in response to every difficult security situation facing us. Instead, we should continue to approach the challenges in the post Cold War world with the combination of strong forces, strong will, quick response, and most of all, wisdom in deciding when and how to use military force.

I'd like to conclude with a favorite quote of mine from the British novelist Graham Greene. He wrote, "There always comes a moment of time when a door opens and lets the future in."

The ending of the Cold War has opened such a door. The future is out there, waiting to come in. By our actions, by our decisions of how we use our military forces, we can influence that future by making the world a safer place for our children and for our grandchildren.

PANEL I

The Vision

Honorable John L. McLucas, Moderator

Dr. Alexander H. Flax

Dr. H. Guyford Stever

Dr. Ivan A. Getting

General Bernard A. Schriever, USAF (Ret.)

Introduction

Honorable John L. McLucas

Seven years ago I was standing right here, and many of my panel members were sitting right there, and we were discussing something which is commemorated in this report—*The 25th Anniversary of the Air Force Studies Board*. The document was prepared by the Academy and here it is, and I hope that we have a similarly nice or even better document to memorialize the meeting that we're having here today.

Some of you know that the person who should be standing here is Bob Seamans. Bob Seamans is only two years older than I, but enough older so that when World War II came along he was already an established professional and I was still in school. Fifty years ago today I was in the U.S. Navy in the Pacific; Bob Seamans was teaching aeronautics at MIT; and all of our panel members were already involved in some kind of Air Force activity. The first meeting of the SAB took place in June of 1946, and by that time I was working for the Air Force. The war was over and I was working at something called the Cambridge Field Station of Watson Laboratories on Eldon Street in Cambridge. It's now the Air Force Cambridge Research Center, I believe, unless they've changed the name again, which they might have.

I have my own version of why we're here today. To have some fun, to pass along some information to the other people. I see most of the old timers are here. I hope there are some young people here listening. Also to honor those who made the business of advising the Air Force what I consider to be a huge success. I don't think it necessarily had to turn out that way. When you think about it, there are a lot of people who give bad advice. The Air Force could have been overcome by that. Then there are a lot of people who give good advice, but the people running the Air Force might have been so thick-headed that they wouldn't accept it. So if you look at the odds of everything working out just right, good advice well used, they're pretty slim. You're going to hear some old names today, names like Arnold and Doolittle, and Kármán. But Ivan Getting asked me to say a word about the situation which existed just before the SAB came into being, specifically he was talking about the pre-World War II climate in which the Army and Navy had to be pretty much self-sufficient. The idea of getting a lot of free advice from outside had not developed. The whole idea of having a massive advisory structure and program had to be invented along with World War II. Several of our panelists are going to speak on that subject.

Our first speaker is Al Flax. His topic is Dr. Theodore von Kármán, before and after the SAB. Now Kármán is associated with many things in Air Force history, one of them is the IAF (International Astronautical Federation). I've been going to those meetings for a long time, and for years I chaired a session on the subject of Mars exploration. About five years ago, I was chairing a session on that subject, and I had a certain time limit I had to stay within and I ran over my time limit. So I cut into the time of the people who were going to come after me on another panel. As a result, I've never been asked to chair another session at the IAF. So I hope we don't get into that same problem today, and if we're going to avoid it, I think I'd better introduce Al Flax.

Early Kármán

Dr. Alexander H. Flax

I think you already have, Mr. Chairman, started down that slippery slope of using up the time limit, maybe I won't do the same thing.

I should first say that I'm really here "doubling in brass" for somebody who could have done this job much better. We had hoped to get Bill Sears, who was a very close associate of Kármán in the years before World War II and subsequently all through the years since he married Kármán's secretary, Mabel. They proved to be the focal point for all of Kármán's former associates and activities and things of that nature.

I think there are a number of people in this room who could give you varied perspectives on Kármán. He was a man of many dimensions. What I've tried to do is to single out those things in his background that have a peculiar bearing on his relationship with the Air Force, his formation of the SAB, and the way he thought.

The first thing you have to know is that he came to this country at the beginning of the 1930s to join the faculty of the California Institute of Technology as part of a program that then-President of Caltech, Robert A. Millikan, a Nobel Prize winning physicist, established in an attempt to build up Caltech as a center of excellence in certain fields. One of the fields he chose was aeronautics. He had in mind the growing importance of the aircraft industry in Southern California.

Kármán had been a student of Ludwig Prandtl, probably in his time the world's leading aeronautical scientist, and he carried on in that tradition. When Kármán became head of the school in Aachen, Germany, he essentially thought the measure of merit was to compete with Prandtl. He tried and in some degree he was successful, particularly in some of his early work on the theory of turbulence. There was a meeting scheduled at which both were supposed to give papers. Kármán came up with the theory of local similarity, which brought in the famous logarithmic law that all aeronautical engineers now use for turbulent boundary layers, and Prandtl withdrew his paper when Kármán gave him an advance copy of his. He also was very gracious in a way that some of our modern researchers are not, and gave Kármán some of the experimental data which he had amassed on the subject prior to the meeting.

Kármán was a strange mixture of an earthly pragmatic person and a very ethereal, visionary scientist. That showed up throughout his career. Before he came to Germany to pursue his advanced degree, he had been in industry. He had worked for a manufacturer of hydraulic machinery in Hungary, his home country. He also served in the Austro-Hungarian army in World War I. While that didn't give him any great insight into military strategy—he was a second lieutenant—he did become intimately involved in the hardware problems of aircraft, engines, and armament.

The most significant development programs he was involved in was developing a captive helicopter drone to replace the observation balloon and reduce its vulnerability. People with fighter aircraft in that day used to count their score not only against other fighters but against observation balloons. During this time, he had very close contact with the German aircraft

industry and he carried on in that tradition when he came to this country. Particularly, he worked with Junkers on both the structural and aerodynamic problems of Junkers' designs.

Upon arriving at Caltech, Kármán set about making it a leading center of aeronautical research and advanced education, carrying over the best features of the German model. In his usual perceptive way, however, he adapted it to the American scene and took advantage of the flexibility and receptiveness to change in American institutions. He carried on the linkages that he had always maintained between his academic interests and industry, and the linkages between theory and practice that had characterized his earlier career. He established connections with the emerging California aircraft industry, particularly with Douglas and Northrop companies whose designs were often investigated in the Caltech wind tunnels. Probably the most famous story had to do with the shaping of an intersection between the body and the wing of the Northrop Alpha and the Douglas TC-3 (that famous C-47). They came to interact with one another on a casual but friendly basis.

The scope of aeronautical research at Caltech under Kármán was very broad. He covered important aspects of aerodynamic structures and propulsion. It's very hard for us to imagine in this day somebody who was such a prominent and preeminent figure in the field who spanned all of these activities in a way that gave him a certain authority. Today you would have to assemble a group of at least 20 people to accomplish the same thing. Interestingly, he was always thinking about how this fit into some future aircraft or what design implications it had. He was a large scale rather than a small scale thinker. By the beginning of World War II, it's fair to say that Kármán and some of his leading students were in the forefront of American aeronautical research.

I remember the first time I saw him in action. It was at an annual meeting of what was then the Institute of the Aeronautical Sciences in the late 1930s. Incidentally, the President at that time presided over some of the meetings. That was Jimmy Doolittle. So the cast of characters was small and interactive. Kármán and a few of his students sat in the front row of the lecture hall in Columbia. The aerospace profession was then poor, and we couldn't afford to meet in a hotel. We met in a lecture hall in the physics department at Columbia. The community was small enough that we all fit in there. Kármán and a few of his students sat in the front row of the lecture hall and critiqued any paper that had the remotest connection with their interests. It came to be regarded as running the gauntlet, and some of us cringed the first time we heard it. But Kármán, in his biography, recounts how surprised he was by that reaction. He argued that in Europe sharp criticism of technical papers was taken for granted. Such criticism was an essential part of scientific and technical discourse and progress. I think with the passage of time, the American scene came to be more like the European scene in this regard. But when he first began to inject this note into the discourse, it was somewhat jarring to many people.

He was regarded as a near legendary figure, but he was also much more benign in personal contacts than in formal meetings. Many sought to make his acquaintance and associate themselves in some way with him, even if only through brief encounters or conversations so that they could later refer to them. Some people described the situation as people moving in orbit around the sun. He was a very commanding figure in that way.

He also insisted that he was not an "ivory tower" scientist. Some people thought it was just an affectation, but in terms of his former interests, his former activities, it was not entirely an

empty claim. At times he appeared to be on one side of the question or the other. He once described a practical man as one who repeated the errors of his predecessors, so people jumped to the conclusion from that that one should not be practical. That was certainly not his view.

As World War II approached, military aircraft were just beginning to enter the flight regimes in which the effects of subsonic compressibility were becoming important. A new phenomena, totally unexpected by engineers who designed those airplanes, was encountered. Kármán's investigations of subsonic compressibility theory suddenly moved from the theoretical to the practical because the new fighters that the nation was counting on to help win the war, the modern generation aircraft like the P-38, P-47, were suddenly encountering compressibility troubles. Kármán was consulted by the Air Force and by company engineers and helped to resolve the issue. Actually it was not resolved by any single solution, it was a matter of understanding a whole set of new flight phenomena. For example, the problem with the P-38 was not solved until the aircraft were already in the field in large numbers. I think the model J was the first one to have the dive flaps that kept them out of trouble.

Kármán's many-sided genius was also evident in his work on some of the difficult problems of structural stabiiity, including the non-linear problem, the buckling of curved shells. He was an active participant all these years not only in the affairs of professional societies, but in the meetings of the NACA and the Congress of Applied Mechanics, and he had essentially received world recognition.

While wartime activities involved Kármán in many issues he remained very much on the cutting edge of the aeronautical technology of that day. He was one of the leaders in the development of rocket technology in this country. He was, along with some of his students, engaged in research on rockets which the Army Air Corps supported as Jet Assisted Takeoff (JATO). Kármán's interests, however, saw far beyond that.

Interestingly, unlike many of the other academic scientists who served as civilians in the war through civilian organizations (like OSRD), Kármán always dealt directly with the military. He was funded by the military. He was at ease with the military. His own military service had given him the feeling that he understood the questions before him from a military as well as academic point of view. His work in rockets eventually led to the formation of the Jet Propulsion Laboratory, and also the Aerojet Corporation, and believe it or not, for a brief period Kármán was the President of the Aerojet General Corporation producing rockets for jet-assisted takeoff. That association didn't work very well, and he had better things to do, so he was replaced after a short period.

Before the end of the war he was consulted by the Air Force, and this was not just General Arnold, but people like Frank Carroll and Benny Chidlaw. All were engaged in projecting the future facilities requirements of the Air Force. They were talking about transonic and supersonic research airplanes, and he had a hand in both. With the coming of the age of supersonic flight, Kármán, in his 1947 Wright Brothers lecture, gave the grand summary of the state of knowledge on supersonic aerodynamics. It was very well attended and really got things underway.

From 1944 onward, he played an active role in the formation and operation of the SAB. But in this same period, as the invasion of Germany took place, Kármán renewed his contacts with the European scientific and technical communities—both among the allies and on the

other side of the line, and that reaffirmed his belief that fundamental science and engineering were and still are essentially international in character.

When the North Atlantic Treaty Alliance was formed, he saw the needs and the opportunities for the member nations to establish mechanisms for cooperation in aerospace research and development. This led to the 1952 creation of the NATO Advisory Group for Aerospace Research and Development (AGARD), which in its original concept was intended to be an international SAB for NATO. It evolved into other forms, but that was the original thought. He was also responsible for establishment of other international institutions, one of them an International School for Advanced Education in Experimental and Theoretical Aerodynamics in Belgium. This was named the Kármán Institute in his honor. From about 1954 onward he served as the full time chairman of AGARD and lived in Paris. He served in that role until his death in 1963.

The Early Scientific Advisory Board

Dr. H. Guyford Stever

In early 1946, when Kármán put together the initial SAB, he depended on the membership of the Scientific Advisory Group which had spent the previous year learning about the last war and thinking about the future. The result was the study, *Toward New Horizons*. But additional members were needed, and were needed steadily over the next decade or so.

General Fogleman yesterday mentioned that General Arnold's charge to the SAG before they made that study suggested that the Air Force had to depend on people outside of the Air Force for a lot of the new World War II developments. He was very anxious for the SAB to capture some of those outside people and bring them in.

Many of these needed new members were available from a generation of scientists and engineers who had actually had much experience in military weaponry—not only in the laboratories, but in the field as well. The NDRC (National Defense Research Committee) was formed in 1940, a year and a half before we got in the war. Dr. Vannevar Bush had easily convinced President Roosevelt that there was a large, untapped reservoir of scientists and engineers in the nation's research universities. Most of them very worried about the situation which developed when France fell and Britain was left standing alone. These men could be enlisted to work military weaponry.

The new NDRC, part of OSRD, was given its own funding approved by the President without going to or through any other unit of the Administration, including the armed forces. It could select its own projects, people, and organization. The divisions and sections (and also their labs) were free to pursue their own independent research and development, to work directly with industry, and to cooperate fully and directly with appropriate units of the armed forces.

Though some units of the armed forces objected to the formation of an outfit that had so much more freedom than they did, most of the military units soon learned that they could get a great deal out of a close relationship with OSRD/NDRC projects. They did, and the Army Air Forces were often leaders in that area.

By war's end, there were nineteen NDRC weaponry divisions, including medical research, also a part of OSRD. Included in the list of successful OSRD/NDRC developments which actually were used in the war were radar, radio counter-measures, proximity fuses, new explosives, treatment for malaria, penicillin manufacturing, radar-guided glide bombs, rockets, and atom bombs.

Shortly after the end of the war, OSRD/NDRC went out of business. Many of the leading scientists that worked in the labs did go back to the universities to begin their careers doing basic research and teaching. Others went to industry and continued in their wartime pursuits, military contracts. Some, and this was very important, joined the growing lists of non-profit think tanks and laboratories, Lincoln Lab, Livermore Lab, and others. Some returned to government jobs. Kármán drew heavily on this.

One of the most successful of the NDRC laboratories was the MIT Radiation Laboratory which started in the fall of 1940, long before we got in the war, and terminated immediately

after the war. It had a record of developing approximately 100 different radar sets, ancillary equipment, airborne, shipborne, and ground radars, and getting them produced for combat use. RadLab didn't invent radar, but it seized upon the gift of the Cavity Magnetron which made microwave radar practical and valuable.

From the early staff of that radiation laboratory, Kármán picked several members for the SAB. Lee DuBridge, Ivan Getting, Dave Griggs, Edward Purcell, Norman Ramsey, Louis Ridenour, Shell Sherwin, Guyford Stever, Jay Scranton, and George Valley. Five of the first six Chief Scientists of the Air Force came from this group. Five were members of the original SAG. The above-named members and others, including SAB members, including Bob Robertson, brought with them not only laboratory experience, but they brought "operational" experience. Many of them had participated, working with the U.S. Army and Navy, particularly with the Army Air Corps.

Some worked, as I did, for the OSRD mission which was established by Jim Conant, in 1940, to exchange technologies and information and people and equipment with British labs and all three British services. That mission expanded when our armed services began to build up in 1942.

Some of our members worked for the British branch of the Radiation Laboratory which MIT had established. Another group worked with the advisory specialist group which was assigned to the United States Strategic Air Force in 1944. We all worked cooperatively. Our activities included advising the Air Corps commanders and their staffs, including General Spaatz, General Doolittle, and General Sam Anderson. We engaged in an exchange of scientific intelligence with the British on radar-guided missiles and radio counter-measures and helped armed services use them. We helped our armed forces at all ranks. This is very interesting. A civilian group doesn't wear rank and they can talk with high ranking officers as well as enlisted men in the field who are installing a radar in an airplane in an emergency.

We helped our armed forces at all ranks to identify, secure, and learn to use devices such as radar. Dave Griggs, one of our members, was one of the leaders there. Of course, there was Ivan Getting's ubiquitous SCR-584 radar [gun laying] equipment which was so vital in defending against the V-1 attacks on London. We advised on the use of radar and counter-measures in the D-Day Invasion and subsequent operations on the continent. We made many technical intelligence missions to the continent to inspect key sites as soon as they were captured.

Through the 1940s and the 1950s the SAB had two great leaders—two of the greatest leaders of our time. Dr. Theodore von Kármán and Dr. James "Jimmy" Doolittle. Kármán had his vision of where science and technology would go and Doolittle held total command of the technologies involved, a full understanding of Air Force operations and needs. More importantly, Doolittle helped get our advice accepted.

Under their leadership, the SAB helped the Air Force establish a continental air defense system, converted its airplanes to supersonic speeds, absorbed the bomb—A-bomb and H-bomb—into their strategic warfare mission, establish intercontinental rocket power missiles, rise to the advent of space flight and satellites, and strengthen military intelligence capability and the R&D labs. Those of us in those days grew to love those two great leaders, and it wasn't simply because they were great leaders of science and military technology, but they were two of

the warmest human beings possible. They were interested in us, in our own successes, in our families.

I went with Kármán on his first trip to the continent just at the end of the war. We visited a laboratory, the Hermann Goering Institute at Folkenrode near Braunschweig. There we found a pristine laboratory, untouched by bombing. It was a great aerodynamic center. The party included Kármán, H.S. Tsien, Hugh Dryden, and George Schairer, a fantastic quartet of aerodynamicists, and they were agog. The German aerodynamicists, A. Buseman and his team, had the theory and experimental data for transonic and supersonic aerodynamics beautifully in order. I sat later with George Schairer of Boeing as he penned the famous telegram to Boeing. "Sweep back the wings of the B-47, data follows."

We went on to visit the famous "salt mines" where the V-1 and V-2 were built. And then we went to visit the great center at Göttingen. Ludwig Prandtl, the great leader, Kármán's teacher was there. He was rather ill. We went to his house and here was the great leader of the past and the great leader of the future meeting together—professor and student. The emotion of their meeting was so great, they really couldn't speak to each other, but just stood and looked at each other for awhile.

The SAB was sustained in the late 1940s and early 1950s by a war experienced cadre of scientists and engineers, but soon it had to depend upon a new generation of potential members from academia, industry, government. A different mix. They got their start from many of the projects that the Air Force had started in ballistic missiles, supersonic aircraft, computers, space technologies, and satellites. It was a great organization.

The SAB in Its Infancy

Dr. Ivan A. Getting

I'm going to read my talk because I can go faster that way. Whether you follow me or not is not important, but I have to finish it. (Laughter)

Guy Stever has described how rapidly the technical working relationships developed between the OSRD with its contracted laboratories, and the Army Air Corps, as well as its various R&D agencies, Wright Field, the Army Signal Corps, the Army Ordnance Corps. However, the penetration of new concepts of weapons and their application to military operations did not automatically flow in a timely manner to the Army/Air Force operational commanders. Links which Van Bush, as head of the independent OSRD had purposely denied himself. In other words, Bush told the military, "Don't tell me how to run my business. I won't tell you how to run your business."

When Secretary of War Stimson, asked Bush for help on how to run things, Bush recommended Edward Bowles—like Bush, a former MIT electrical engineering professor. Stimson appointed Bowles to the position of Assistant to the Secretary of War in April 1942. He was authorized to speak for him on all matters of electronics including radar, communications, meteorology, and navigation. Subsequently, after discussions with General Arnold, this role and authority was extended to Bowles also as consultant to the Commanding General of the Army Air Corps. According to the Army Air Force memorandum 20-11, 2 September 1943, Bowles was to act with the commanding general "through the medium of the Chief of Air Staff as well as through direct coordination with several Assistant Chiefs of Air Staff and the Air Communications Officer in the determination of policy, in the initiation of projects, and in all matters of planning, training, organization, procurement, and operations in any way concerned with communications."

Dr. Bowles called upon many scientists as expert consultants to the Secretary of the War—some full time and some part time—to apply operational analysis to military operations, to inform Army Air Force commanders on the impact of new electronic capabilities, to prepare plans for the integration of new concepts into warfare, as well as develop plans for equipment procurement, and to actually assist battle commanders by participating in the field.

Among his recruits were David Griggs, Louis Ridenour, Julius Stratten, Norman Ramsey, Dale Corsin, William Shockley, Phillip Orse, and myself. Many were members of OSRD contractors such as the MIT Radiation Laboratory, and the British Radiation Laboratory, providing C-2 scientific support. You will recognize that many of these men later became members of the SAB, and Chief Scientists of the Air Force.

Dr. Bowles also injected himself into procurement of weapon systems as well as organizational changes within the War Department. As the technical innovations of airborne radar and air warfare in general advanced, including ground-based early warning radar and tactical aircraft ground control radar, he drafted for General Marshall's signature a letter transferring the R&D of such equipment from the Army Signal Corps to the Army Air Force. This contributed to the eventual separation of the Air Force from the Army as a separate military department.

As the war in Europe was approaching the end, General Arnold reviewed the changes in air warfare which had occurred during the war through the intensive application of science and technology. He turned to his old friend Kármán to pull together a Scientific Advisory Group, and Kármán in turn asked Bush and Bowles for help in setting up the membership. The SAG first met in January 1945. In General Arnold's address to the group at its first meeting, he said, "I don't think we dare muddle through the next 20 years the way we have the last 20." The first meeting of the follow-on SAB was held in June 1946. Its establishment did provide a course for clear sailing.

With the defeat of Japan a year earlier, the United States had entered its usual after-war syndrome, very much like we are currently undergoing with the end of the Cold War; demobilization of the military forces, cutback of funding for both military research and production, dislocation of people, unemployment, and of course, changes resulting from congressional and legislative initiatives.

Perhaps the most important change was the National Security Act of 1947 whose principal impact was the separation of the Air Force from the Army. The Act also established, at a joint level, a Research and Development Board (RDB) chaired by a presidentially appointed civilian with broad authority, preparing integrated R&D programs, advising on scientific trends, formulating R&D policy, and examining interaction of R&D and strategy, and advising the Joint Chiefs of Staff. Vannevar Bush was the first Chairman in 1948, followed by Karl Compton of MIT in 1949. Congress then amended the 1947 Act again in 1949 by establishing a Department of Defense with a single Secretary of Defense, a member of the President's cabinet. The three services no longer were separate executive departments. The amendment also gave the Air Force three years to integrate the remaining pieces of the Army as approved by the Secretary of Defense.

It is not surprising, therefore, that the period of 1945 to 1950 was what can be described as "hectic" for the leadership of the Air Force. While Kármán and members of the new SAB continued with his study of Nazi aeronautics, the newly born SAB suffered neglect.

Thomas Sturm's, *The U.S. Air Force Scientific Advisory Board: Its First 20 Years*, summarized it succinctly for the year 1946, "The simple truth was, that no one called on them to do anything."

Allow me to put it in a more personal way. While I was an original and still a member of the SAB at that time, on the formation of the RDB, I was invited to become the Chairman of the Radar Panel of the Electronics Committee chaired by Don Quarles. There was competition and much duplication among the three services. The meetings usually held at the Pentagon kept me very busy. The work load was superimposed on top of my teaching and research at MIT. So in fairness, I resigned from the SAB.

Now I should point out that during the SAG's encounters, Kármán had treated me much as a son. He was old enough to be my father, and his forbearers and mine had both come from Central Europe. We were, sort-of, countrymen. On the occasion of one of my RDB meetings, while walking down a corridor of the Pentagon, I ran into Kármán. In his thick Hungarian accent he said, "Why did you resign from the SAB?" I truthfully replied, "Because you weren't doing anything." He drew himself up to his 5'2" and replied, "Schweinhund," turned his back to

me, and walked away. My friends tried to console me at being called a "pig-dog," a Hungarian term used only with family members. (Laughter)

Soon after this encounter, Kármán went to work reforming the SAB. On 15 April 1948, General Tooey Spaatz, General Hoyt Vandenburg, and General Laurence Craigie met with Kármán and produced a plan which became the bible. The SAB was to be a part of the office of the Chief of Staff. There would be a civilian director of the SAB supported by a military staff reporting to the director of R&D, then an office under the Deputy Chief of Materiel, but in his SAB role, reporting directly to the Chief. Within a month, Regulation 20-30 was published. The SAB now had a formal Air Force charter, but it was yet to be tested.

The plan incorporated lessons of World War II regarding the relationship between the military and scientific communities as practiced by General Arnold, by Vannevar Bush, and by Dr. Edward Bowles. The membership consisted of non-DoD scientists and engineers. The SAB members would have direct access to all elements of the Air Force, and could be called on for advice in any area of Air Force operations as appropriate.

Would the SAB with such a broad charter be accepted by the working Air Force? The first major test resulted from the so-called Ridenour/Doolittle report. While the SAB operated through studies assigned to its technical panels which were then reviewed by the Board as a whole, provision was also made for ad hoc committees responding to broad issues. General Vandenburg was concerned about whether the structure of the Air Force which emphasized military readiness and placed too little emphasis on long range issues with the sacrifice of adequate financial and management support of R&D. Sounds like today, doesn't it?

In response, an ad hoc SAB committee was appointed with Louis Ridenour as chairman. Louis had been both a major player at the wartime radiation laboratory, as well as in Bowles' office. All the members were leaders in scientific administration. However, no matter how brilliant their report, (published on 21 September 1949) it probably would not have been accepted by the Air Force had not Jimmy Doolittle played a double role—working member of the committee, as well as special confidante and advisor to the Chief, General Vandenburg. General Vandenburg accepted the report. The net result was the establishment of the Deputy Chief of Staff Development: the future; co-equal with the Deputy Chief of Staff Materiel: the now; and a voting member of the Air Council. The Deputy Chief of Staff for Development had the Director of Research and Development reporting to him, the Director of Requirements, the Assistant for Programming, and the Assistant for Development Planning. In addition, a new command was established, ARDC (Air Research and Development Command), with responsibility for implementing all Air Force R&D. Unfortunately, the strong bond of the Materiel advocates was able to withhold warrant and contracting authority from the new command. But this was corrected later.

These actions on the part of the Chief firmly established the standing of the SAB at all levels. Concurrently, the SAB electronics panel, with George Valley as chairman, was confronted with a very critical national problem. The Soviets, in 1949, had demonstrated their atomic bomb much sooner than had been anticipated. They also possessed long range bombers. The United States was no longer safe from devastating attack, and our air defense capabilities were essentially non-existent. George and his panel took on the job of inventing new concepts for air defense.

In the mean time, the late 1940s, the Air Force Command under General Gordon Saville, had been created with headquarters on Long Island, but he had no night fighters, and ground warning radars had seen no improvement in ground clutter rejection since World War II. In short, the United States and the Air Force had been caught "with their pants down."

As the Chairman of the DoD RDB Panel, I had the privilege of watching General Saville break every rule in the book. He awarded the new Ford company, called Hughes Aircraft, a sole source contract to manufacture copies of the GE airborne radar originally designed by RadLab during World War II. He had these installed in two-seat trainers. Then he sought my support as Chairman of the DoD RDB Panel to order a sole source contract to Hughes for an air-to-air missile not yet designed. Armed with my comments regarding the quality of the scientists and engineers at Hughes, he ordered a contract for development of the Falcon Missile. By 1950, Saville had become the first Deputy Chief of Staff for Development. Among his early moves was recruiting me as his Assistant for Development Planning.

With the outbreak of the war in Korea on 25 June 1950, and the danger of nuclear attack by the Soviet Union, and with the advice of Mervin Kelly, head of Bell Labs and later successor to Kármán as the head of SAB, I accepted the challenge and took on the role of a general officer with a deputy named Colonel Benny Schriever. George Valley's committee, dubbed ADSEC (Air Defense Systems Engineering Committee), was meeting every Friday night at the Air Force Cambridge Research Laboratory, one of the post-war fragments of the MIT RadLab. They conceived a distributed system of small radars mounted on telegraph poles. All the radars communicated to a central display system. It was clear to me in my new Air Force role that as brilliant as the SAB effort, the committee of part-time geniuses, including Al Donovan, Stark Draper, Guy Stever, and supported by John Marquetti, Director of the Air Force Cambridge Laboratory, was sub-critical in size, and that an organized, major, full-time laboratory effort would be required for the project.

To sum up, General Saville, Louis Ridenour (then Chief Scientist of the Air Force), and I persuaded Jim Killian and Jay Stratton of MIT to set up a full-time laboratory named Lincoln Laboratory. In the process, Jay Forrester, Bob Evert with their O&R sponsored whirlwind digital computer were absorbed in what became the SAGE system of air defense, and the digital age was born. The exploratory work of George Valley's SAB ADSEC committee had been seminal.

In the summer of 1951, the Korean War was put on ice, so to speak. The threat or a Third World War had been averted. However, the Soviet threat of an attack on Western Europe with possible escalation of a nuclear attack on the United States continued. In 1951, the development by the Atomic Energy Commission of a thermonuclear bomb was being delayed by Oppenheimer's Advisory Committee, contrary to President Truman's go-ahead order of 1949. The Air Force did, in 1951, contractually support Edward Teller's theoretical study on fusion weapons at the University of Chicago.

I shall here pass on to the next speaker, General Schriever, the role of the SAB in a thermonuclear era during the second half of the first decade of the SAB.

The Second Five Years

General Bernard A. Schriever, USAF (Ret.)

Well, I can tell all of you that being tail end Charlie to four scientists is certain to create a time deficit. I'm speaking on a time deficit. Fortunately, I have some rough notes here, and I've been scratching away at them, so I'll try to reduce the deficit somewhat. Like in politics, if you have a $300 billion deficit one year and you reduce it to $295 billion the next year, the politicians will say, "We have reduced the deficit." That's about the position I'm in. I'm working on deficit time.

I'd like to start out by saying a few things about General Hap Arnold, because it turned out that in my career in the Air Force I developed a very close relationship with Hap Arnold.

To start out with, he was my first commander at March Air Force Base in 1933 when I finished flying school. Our personal relationship evolved to the point that, when I got married in 1938, he substituted for my father-in-law who couldn't come up from Panama. I was fortunate to have someone of that stature providing me some early training.

In my opinion, he was the greatest leader and visionary that we've ever had in the Air Force. I asked Bruce Arnold who worked for me, one of his sons, about his father many years later, and why he was such a visionary. He put this together and I'd like to read it, because I believe it's absolutely true from my own observation.

"He would be the first to admit that he was no genius, but he was an extremely innovative person and was able to utilize his imagination in a way that the crudest models could, in his eyes, become a successful product in the future. He was a very determined man and from the earliest times believed in the future of airpower, and never changed his position even in the face of strong criticism and pressure."

I think that's one factor that we in the military need to be really sure that we continue. We need to say it like it is within the halls where the decisions are made, we have to pursue what we believe to be necessary for national security. His interest in new things never waivered. I can assure you that this was my observation of General Arnold and fits him perfectly.

He certainly did have a vision for the future. I returned from the Pacific after about three and a half years during World War II and reported to the Pentagon in January 1946. From a lieutenant colonel, he had risen to Five-Star General of the Army. We were still the Army, but we called it the Army Air Forces at that time.

He called me into his office and he said, "Benny, the national laboratories are being liquidated. Scientists are returning to their universities. Major science and technology breakthroughs have occurred during the war which will change completely the nature of future warfare. We have started and must maintain relationships with the scientific community. I would like for you to establish an office under the Director of R&D at the Air Staff level, maintaining this relationship which has been established. We called it the Office of Scientific Liaison which I then headed for four years in the Pentagon, from 1946 through 1949. Under Kármán's leadership, with Doolittle, Merv Kelly, Ridenour, and others, the job was done. And even to this day we

have that close relationship with the scientific community as demonstrated by this particular meeting.

I could speak about both Hap Arnold and Kármán much longer, but I've been asked to cover the SAB role in the ICBM program, the introduction of solid propellants to the ballistic missile program, and the creation of the Division Advisory Groups, the DAGs. If I got to talking about the establishment of ARDC and the establishment of the Air Force Systems Command and their demise during the past administration, I would be here all day, so I'll save that for another time. Everybody knows my position on that, anyway. (Laughter)

In each of the three above, ICBMs, solid propellants, and creation of the Division Advisory Groups, the SAB played a very critical role. Let me talk about the ICBM.

Dr. Teller is sitting here. We had an SAB spring meeting at Patrick Air Force Base in 1953, and I made a presentation there about a low altitude bomber. Von Neumann and Teller made presentations (and I know they hadn't coordinated them), that stated it was feasible to think about having a dry, 1500 pound, 1 megaton bomb available by 1960. The first nuclear weapon dropped was a wet device. As you know, the dry weapon changed the whole picture with respect to the feasibility of an ICBM program.

I went to Princeton the following week with Teddy Walkowicz. His name has not been mentioned, but he was very close to Kármán and he knew von Neumann well. I went to Princeton because it was closer, Teller being on the West Coast. After about half a day's discussion, it was decided that the best approach to really providing the kind of institutional position with respect to this projection that had been made by Teller and von Neumann would be to set up a special ad hoc committee of the SAB to confirm that this was, in fact, possible.

The special committee submitted their report in June of 1953, which confirmed that the von Neumann and Teller projects were feasible and could be achieved by 1960. Incidentally, this committee was made up of practically every top nuclear physicist that we had in the country.

At about the same time, Trevor Gardner had been asked to make a study for the Secretary of Defense on strategic missiles. We had the SNARC, the Navajo, and now we were thinking about a ballistic missile program. A study group under Gardner was established, and had many of the same members that we had on the SAB group, to study the feasibility of proceeding with an ICBM program. They submitted their report in February of 1954, and made the recommendation to proceed with highest national priority with an ICBM program. Von Neumann had made an amendment to the Teapot Report, which was "Top Secret" at the time, but they're available today. While we did not have hard intelligence with respect to what the Soviets were doing, it was certainly clear that the introduction of a long range ballistic missile would change the strategic balance, and that we had to get to that point as quickly as we could.

The recommendations were accepted by the Air Force and passed up to the Office of the Secretary of Defense, and by 2 August 1954, the Western Development Division had been established, and I was the first commander of that division. The von Neumann committee continued to be an advisory committee on ballistic missile activities, and later became a DoD advisory committee on ballistic missiles. To the SAB, the Scientific Advisory Board, I give full credit for providing the credibility that we needed to proceed on a program of the magnitude of

the ballistic missile program. There was still so much to be done with respect to development and testing. We had rocket engines, but we had very little in the way of guidance. We had only the promise of the best scientists in this country that we could achieve this warhead of 1500 pounds and 1 megaton. But we proceeded.

Let me talk now about the solid propellant program. As far as the military was concerned, there were some very, very significant advantages in a solid propellant missile from a logistics standpoint and from an operational standpoint (As far as reaction time, handling, quick response time).

In the summer of 1955, I asked Dr. von Kármán who, incidentally, I asked to do many things while I was running the Western Development Division, and then subsequently the Air Research and Development Command, and then the Air Force Systems Command, and he never turned down a single request I made of him. I had a very close relationships with Dr. von Kármán, and he was a magnificent individual in every respect. I cherish our relationship very much.

This study was made out on the West Coast in the summer of 1955. They came out with the findings that it was feasible to think about a long range solid propellant ballistic missile. There were some technologies that they felt should be demonstrated, such as mass fraction, the guidance of the solid propellant motors, and the precise motor shutdown. Fortunately, I had quite a bit of flexibility in the use of the ballistic missile budget and for our technology/test effort. We conducted the test program for about six months with all of the solid propellant companies in the U.S. actually participating. We satisfied all of our superiors in the Pentagon and in Congress that the advantages of a solid propellant missile were so great, and that feasibility had been established, we started the Minuteman and Polaris program in 1957. The Navy hadn't participated in the Air Force study concerning the solid propellant, but we had made available to them all of the solid propellant information, so they started their Polaris program, and in my view, the Minuteman and Polaris programs were probably among the most successful and timely—both in schedule and cost—that we ever have had in this country. As a matter of fact, both were put into the operational inventory in less than five years from the initiation of the program.

Toward New Horizons, certainly provided the guidelines for the Air Force for many years, and set the stage for what we have today. The country and the Air Force really were very fortunate that Arnold and von Kármán came together just at the right time. Arnold's vision triggered the SAB, with the help of Kármán of course, and Kármán provided the leadership which made the SAB a major player in shaping the Air Force, now certainly considered the world's best. I can assure those younger officers that are in the audience and the rest of the Air Force, that it will be a very, very tough act to follow during the next 50 years.

PANEL II

Fulfilling the Vision

Honorable Hans Mark, Moderator

Dr. Courtland D. Perkins

Mr. Harry J. Hillaker

Dr. Robert G. Loewy

General Lew Allen, Jr., USAF (Ret.)

Introduction

Honorable Hans Mark

The subject of this panel is the next ten years. Roughly speaking, the 1960s, 1970s, the Cold War. We're going to focus on three things. One is the things we did that failed. That is, the Air Force Scientific Advisory Board did studies and made recommendations that turned out to be wrong. There was aircraft nuclear propulsion; there was high energy laser weapons. I don't know anybody here (except maybe Edward) who remembers the ARGUS project. These were all very interesting things that had to be looked at, and money had to be spent on them, but they weren't done.

The second topic has to do with something that has already been mentioned, but really is terribly important. That is the maintenance, in the Air Force, people who can receive advice from bodies like the Scientific Advisory Board; technically trained and sophisticated military folks.

Lastly, it was during this period that a more or less permanent relationship between the Pentagon and the defense industry was established. Looking at that facet is also something that was very important in this period.

It's a pleasure for me first to introduce, again, someone who needs no introduction, and that's Court Perkins. Court holds several records. He was twice Chairman of the SAB, the other record, you must be the longest chairman of an academic department, longest serving chairman ever; 30 years as Chairman of the Department of Aeronautics at Princeton. (Applause) I know that's hard, because I was chairman of an academic department, and I only lasted five years. He also served as Assistant Secretary of the Air Force for R&D, and was Chief Scientist of the Air Force, and finally, President of the organization which is our host—the National Academy of Engineering. It's a great pleasure for me to introduce Court Perkins.

Not All Success

Dr. Courtland D. Perkins

It was 21 years that I was chairman at Princeton. My successor Bob White is somewhere in the audience. I don't know whether it went uphill or downhill from that point. We had a good time there, and we had some real good students.

At any rate, it's a great pleasure to be part of this activity. Our panel has a different mission than the earlier one which was historic. To prepare for my part, I listed about eight subjects, and then as people kept talking, I kept crossing them out, saying "well we can't talk about that because Stever just did that," or "Schriever said this," or "Getting...Getting says everything."(Laughter)

First, I want to say that when I was Chief Scientist we made sure that this SAB reported to the Chief of Staff, and that the Secretary was not involved. That was exactly the way it was (At least we were told that at the time). It became obvious as I went into that job that this was really a bad steer. All the time I was Chief Scientist, I worked very closely with Dick Horner who was Assistant Secretary of R&D, I worked closely with Joe Charyk who at that time was Under Secretary of the Air Force. It became obvious that you could not just have the SAB operating outside the interests of the top secretarial staff. They had to be coordinated. I spent a good deal of my last year as Assistant Secretary of R&D fixing that. That was fixed, probably by Al Flax who followed me a couple of evolutions later. We changed the regulations of the Air Force so that the SAB would report to both the Chairman and the Secretary. There are a lot of people out there who thought I was one who was against that. That's not true. I was for putting these two together, and if it hadn't been the case, we certainly wouldn't have had Sheila here running this meeting today. That was one point I wanted to make.

The only other thing I wanted to say is that when this whole session started this morning, we had three or four members of the Air Force band playing over in the corner. That reminded me of the very first meeting of the Air Force Scientific Advisory Board which took place in 1946. As we heard, General Spaatz was Chief of Staff at that time, and General Vandenburg was his Vice Chief, and we had our first meeting at Bolling Field. It was beautifully staffed by Curtis LeMay who was Deputy Chief of Staff for R&D. He had assigned all his colonels to carry our bags. So as the SAB walked across to go to this meeting, there was a line of full colonels carrying our bags. This seemed ludicrous to us, but it seemed pretty good to General LeMay. (Laughter)

We had the meeting, and then the first dinner was at the Bolling Field Officer's Club—different than it is now. They had a great big dining room, and in the middle of the dining room was a great curtain shielding off half of the dining room. As we sat down you could hear noises back of that curtain. So everybody wondered what was behind the curtain. I was sitting next to General Vandenburg, and he said, "Do you know what's behind that curtain?" I said, "No, I can't imagine what it is." He said, "We'll show you in a minute. General Spaatz is a little deaf and he likes his music loud."

So just as he said that, the curtain parted and there was the entire Air Force band, not just three or four members, the entire band, and it blew us out of the room. They played "Shortening

Bread," and all those good things, and General Spaatz thought it was just the greatest. That was the first entertainment for the SAB. Enough history.

We were to talk about specific programs and how the SAB got into them. We're not going to talk about the national scene, we're talking about the SAB and how it worked in the 1960s and 1970s. It was a very, very interesting time. It was a lot different than what you in the SAB are dealing with today. We had 10 or 15 programs in progress. We were spending quite a bit of money on them and many ending up more or less shredded. It was a very interesting time to be on the SAB, and as it was pointed out, I served across that time period in several positions.

So the question is, which of these exercises should I talk about? At one time I wrote a paper which I called, "My Six Failures." What I meant by that was that during my tours in the Pentagon I worked specifically on six programs that actually failed, and probably would have been better if they hadn't started (or at least been stopped sooner than they had). One of them was actually a success. They happened to be the nuclear propelled bomber, the B-70, the Sky Bolt, Dinosaur, and the XC-142 which was a V-stall airplane. They all ballooned up and actually got into the air, most of them got into the air, but were inappropriate for what was going on at the time, and they died. So the SAB had been involved with programs that sometimes didn't work.

Out of this group of possibilities I decided to talk a little bit about the start of the TFX program, later the F-111, which was originally included as one of these failures, but it actually wasn't. We actually built the airplane and it actually did a good job.

How did the SAB deal with the TFX or the F-111? From my vantage point—it might not be somebody else's vantage point because everybody saw it a little bit differently—I got into the TFX program during the time I was serving as Assistant Secretary of the Air Force for R&D. One morning into my office came a very eminent NACA researcher, John Stack, accompanied by General Everest who was commander of TAC. These two gentlemen were very interesting, and they had been playing golf together down at Langley Field where they were both based. Between Stack and Everest, they thought up this idea of an attack airplane. Remember, General Everest headed TAC. He wanted TAC to have a more important role than they had at the time, and if this meant edging a little bit into SAC, that was all right with him.

In the meantime, John Stack of the NACA had thought up this idea of variable swept-wing technology. They decided to think up a new tactical airplane which would be up on the borderline with SAC. The program would be a major effort and introduce a brand new technology that would solve a very difficult problem. They proposed this new program. They had sold it, or tried to sell it, around the Air Force but they ended up in my office as Assistant Secretary. I knew both of them rather intimately, so they came in to give me a briefing on this new airplane which was going to be called "TFX requirement." But it was Stack and General Everest who were promoting it. They had an airplane that was going to weigh 50,000 pounds, and it was going to have a 400-600 mile range on the deck supersonic, Mach 1.2. When the wings were swept forward again, it could go subsonic at about .8 Mach number at a considerable range. This was their original concept. The key was variable swept wings. You heard the story about George Schairer visiting the Germans and telling the Boeing company to sweep the wings of the B-47 back, which of course was very successful.

The TFX now was an idea that had been kicking around and its biggest promoters were Stack and Everest who were selling this concept in the Pentagon. The thing that interested all of us was the claim that they were going to build it to weigh 50,000 pounds.

What you do then is you call up the SAB. Here I am the Assistant Secretary, I knew some of these things, but not enough to fight it. I said 50,000 pounds does seem to be a little impossible. So I sent it to the SAB and they sent it to Wright Field, and the answer came back that it was going to weigh something like 120,000 pounds, not 50,000 pounds. So that would have killed the project right then, except we sent the possibility out to industry, and it was ratcheted down to where finally it weighed somewhere around 60,000 or 70,000 pounds. At that point it became feasible as a requirement, and so I had the job of selling that requirement to Herb York who at the time was DDR&E.

To show the complications of this sort of thing, as soon as the Navy heard that the Air Force was promoting an airplane with this sort of a mission, they immediately reacted negatively, naturally, to the idea. As a matter of fact, the Navy wanted us to buy one of their airplanes. It was a North American A-3J. The British also came over and they had an airplane which they were working on. They wanted us to buy this airplane. I told Edwards, who was head of the British aircraft project, the Air Force would be much more likely to buy the British airplane than the Navy airplane. (Laughter) Then he sent me a great model of this airplane, and it had a big "U.S. Air Force" on the side and it was made by the British. The Navy gave me a model of the A-3J, so I had all these three airplanes lined up. But the Air Force was pretty well dedicated to pushing the TFX and did so during my tour there.

It wasn't easy because we were fighting the Navy, the British, SAC, you name it. Most of the Air Force was against this airplane. So it had a very rocky road. The last thing I did as Assistant Secretary of the Air Force was to get John Ruble, who was the Deputy head of R&D in the Defense Department, to help Herb York sign off on this requirement. The TFX requirement was signed off, and it was sent up then to the OSD for approval. It got to that office just as the elections were taking place, and it became obvious to the incumbents that they were not going to win, that the Republicans were going to be out (so it's kind of opposite what happened just recently). The Secretary of the Navy wisely said, "I'm not going to sign this requirement because we're going to have a new President, we may have a new DDR&E." So things just held there.

In the mean time the Navy, in their very capable way, undermined this requirement as fast as they could, so the TFX was on shaky ground. There was even a suggestion that the Navy could use this TFX. They, of course, went ape over that possibility. The net result of this was that the TFX was in limbo until Kennedy took office.

Then McNamara appeared on the scene. One thing McNamara did, and I know a lot of you recognize it, he could make decisions—hard ones, fast. He may not have made the right ones...(Laughter)...but he made them. The interesting thing was that one of the first requirements he saw was the TFX requirement. He immediately said, "this is just what we need," because this airplane can be used by the Navy and the Air Force, everybody was going to use the TFX. That was not exactly what the Navy had in mind. At any rate, McNamara was a pretty strong guy and he got this requirement put in, and the competition was started on the airplane. The Navy then adroitly decided they ought to have a Navy model which became the F-111B. The net result was

that the program started mainly because McNamara was for it, surprisingly so. The Navy was shaken to the core by this whole business.

So we started the TFX program. The Navy was fighting this requirement, and they had a Deputy Chief of Naval Operations for R&D, or for aircraft at the time, named Admiral Perry. Admiral Perry was a ponderous, big man. He had a great white beard, and he was pretty impressive. He was in charge of Navy aeronautical activities. So he came into my office in the Pentagon. He called it that "... damned Air Force requirement," and he said, "I'm going down there and I'm going to really solve the problem of this ... damned Air Force requirement [the TFX]. I'm going right down to Langley Field and see General Everest," who was commander of TAC, "and I'm going to tell him that this is no good and he should get rid of it."

Perry was a three star admiral, and Everest was a four star Air Force general, and head of TAC. So I couldn't wait to hear what happened. (Laughter) He came back from this visit and when he came into my office I said, "Did you tell General Everest about your objection to the TFX?" He said, "I did. I went to his office and I said, Hack," he called him Hack. "Hack, that TFX requirement of yours is a ... damned phony," pounding on the desk.

I said, "What happened?" He said, "Everest threw me out!" (Laughter) That was the end of the Navy effort to stop the TFX. They never did stop it. They finally got out of the program by adroit maneuvering, so it ended up we in the Air Force had a TFX.

During that time the SAB aircraft panel was involved with the technologies of this swept wing airplane. I don't know whether Al Flax was running it at that time, but there was all sorts of input on whether we should build this airplane or not. The SAB was the key to the Secretary's position. I want to again stress the point, by this time the Secretaries were definitely in the act. They were not pushed aside.

In any event, we had the TFX and at the time we had another big airplane that most people remember called the C-5A. The C-5A was being developed at about that same time. It was the result of one of Benny Schriever's pet programs, *Project Forecast.* They were selling the C-5A as the next straight Air Force project. The loser of that competition, by the way, was Boeing. Their proposal was then converted by Boeing to the 747 which was an enormously successful airplane.

While I was connected with the SAB, we had these two big programs—the TFX program and the C-5A program. One of the most active people in this program was Al Flax who was definitely involved with the engines. However, as time went on, the TFX had to be useable and the performance objectives were not usually met. They certainly were not met in the case of TFX or in the case of C-5A. The only question then was how to react. What do you do if you're the Air Force and you have an overweight airplane?

The same thing was happening at Boeing. Boeing built the 747, it was overweight. What do you do? I'll start with Boeing first.

At that time, I was serving as a Director of American Airlines, one of the purchasers of this airplane. We had an airplane that was overweight and did not meet the specification as originally set down by the airlines. At that point there was a meeting of the airlines, Boeing, and the propulsion people to see what they could do. Each one modified their requirements a bit. The 747 cruising Mach number came down, the takeoff run was reduced a little bit, the engine

company gave them 3,000 pounds more thrust, and Boeing took about 3,000 or 4,000 pounds of weight out, and the net result was the 747 which was a very successful airplane.

In the Air Force's case, they were very hard nosed about their contract. It turned out that the propulsion system met the specifications. It was within weight. The weight empty was off. Who was responsible? Well, Lockheed was responsible so the Air Force said to Lockheed, "Take the weight out." They took the weight out of the wing, a lot of it, at which point they reduced the usefulness of the airplane to a point where some time later the Air Force had to rebuild the wings on the airplane.

So one thing about that that was learned; if you're building a new airplane try to compromise across these entities of technology to make a useful airplane and not try to shoot somebody in the foot to get it fixed.

At any rate, the SAB was involved and they immediately became more involved as both of these airplanes flew and got into operation. They both were very heavily loaded airplanes, and they both were made with very high strength materials, steels. The TFX had to have a wing box that would carry all these loads and had wings that swept back and forward. Of course it was much heavier than they had anticipated, so we had a TFX problem. The C-5A had the same sort of problem. The wings were all overloaded, and they were getting stress cracks in the wings. So we called on the SAB.

We told the SAB about these problems. We have this TFX which is having a wing box problem, we have the C-5A which has other materiel problems. From that, we created two major ad hoc committees. The first one was chaired by Holt Ashley from Stanford which dealt with the TFX. They worked on the TFX, and actually found a temporary solution while they rebuilt a new wing box. The net results was that the Air Force was using the SAB to fix this wing box problem.

One of the interesting aspects of this was that although they did figure out a fix, the problem was transferring that fix to the operational Air Force. Before any F-111 flew, it had to be released by the Air Force Scientific Advisory Board panel which, of course, was getting a bit away from its mission. It took awhile to fix that. But eventually the TFX flew and was moderately successful as an airplane.

The Board worked on the C-5A under the direction of Ray Bisplinghoff who was chairman of this ad hoc committee. They studied it hard, they fixed the problem and they got big letters from the Secretary. We did a good job.

Pushing the Limits of Technology

Mr. Harry Hillaker

You've heard two of the speakers talk about the TFX/F-111. I was initially Assistant Project Engineer on that. Being just an Assistant Project Engineer, and knowing the difficulties we were having in the U.S. Navy, I was selected to be the first person to contact the Navy on the TFX. I had a pretty good idea where I stood.

I recall this instance very vividly. When this admiral found out I was from Fort Worth he said, "What are you guys doing in this competition? You don't have any experience on a fighter airplane, let alone a Navy airplane." I said, "Admiral, I take exception to that. I started my career on a Navy airplane." When he said, "What was that?" and I said "PBY," he said, "You should have quit when you were ahead." (Laughter) We had all the warning we needed, but didn't heed it.

From my perspective for fulfilling the vision, the SAB seeds planted by General Arnold and Dr. von Kármán germinated and blossomed. The Air Force embarked on a rather profound ascendancy into maturity. The coming of age occurred when airplanes transitioned from not much more than mere airframes into weapon systems by capitalizing more fully on a broad spectrum of technologies. The products of those technologies is what gave the Air Force efficient combat capabilities and effectiveness to elevate airpower to a level which perhaps even exceeded that of land and sea power. The pursuit and insertion of these advancing technologies, such as supersonic aerodynamics, were the hallmarks of that ascension. The SAB, likewise, came of age as the technologies became increasingly advanced. The more advanced the technologies were, the more involved the SAB became.

Paragraph 4-8 of AFM-1, it's the only Air Force manual I've ever read, is on Air Force doctrine. It states, "The challenges to equip today's forces sufficiently while developing aerospace forces to fight and win tomorrow's war, the capability to win tomorrow's war, demands that the Air Force research and development efforts must not only exploit new technologies, they must also push the limits of technology to discovery and breakthrough." I want to note, "push the limits of technology to discovery and breakthrough."

Fulfilling the intent of that part of the doctrine, "pushing the limits of technology," characterized the pursuit and insertion of advanced technologies in innovative design concepts during these evolving years and were certainly the catalyst that propelled the Air Force to a world class power.

The environment in those days was such that the advanced technologies and innovative concepts that offered high potential operational enhancements could be pursued with a reasonable degree of freedom. We were neither constrained nor dependent on an endorsed operational need. The environment was such that there was considerable freedom to pursue many advanced technologies and concepts. We are concerned about that today. The pursuits were not necessarily open-ended. They did have a reasonable degree of assured success, but not an assured chance of success. We didn't have to wait or depend upon a stated operational need. We were able to develop technologies and concepts that had a future. We didn't have to wait until the future asked for the technologies that it took to fulfill that future.

The SAB with our broad spectrum of expertise and detached involvement played a very significant role in the pursuit of those promising technologies and in their eventual insertion into an operational system or vehicle. The SAB standing panels which I participated in have conducted independent assessments of the quality of the individual tasks, the technology area plans by providing guidance as to their adequacy, giving them sanity checks by assuring that they were consistent with the laws of physics, identifying their weaknesses, their omissions, their excesses, and their strengths. I think this has been one of the two most prominent roles of the SAB.

When advanced technologies or concepts failed to measure up to their promises or suffered failures that impaired their operational benefits, SAB ad hoc study groups were formed to provide an independent evaluation of the problem, and to offer candid recommendations or potential solutions. These have already been discussed. I think the ad hoc study role is where the SAB has been quite visible and very useful.

Initially the scope and direction of the science and technology plans prepared yearly by the laboratories and their appropriate directorates, and their subsequent insertion into forum were reasonably straight forward. The thrust produced in those plans, the scope and direction, were dominated by a single, well defined and characterized threat. There was a plethora of opportunities for the insertion of the products of those plans. The passing of time, however, brought a dramatic change that has caused us to be increasingly more deliberate and discriminating in the number and nature of our science and technology thrusts.

In the 1950s, the U.S. was engaged in fourty-eight aircraft programs, including both research and experimental vehicles. The Air Force was either directly involved or teamed in thirty of those. In the 1960s, there were sixteen programs and the Air Force was involved in thirteen. In the 1970s that diminished to fourteen and the Air Force was involved in eight of these. In the 1980s there were only seven. So far in the 1990s, I can count only three. At least in part, this is certainly a consequence of our advances in technology. I would certainly expect advances in technologies to produce a higher per unit capability of each of our vehicles.

During the subject period, improvements in aerodynamic propulsion and structural material technology doubled the individual effectiveness of our airframes. Accompanied with that, the advancements in avionics technologies in both our bomb/nav systems and flight control systems, more than doubled their effectiveness making the airplane a more complete and a more mature vehicle.

Although we realized tremendous gains in combat effectiveness with the insertion of those technologies, they weren't accompanied by particularly significant improvements in affordability. The very sophistication and complexities engendered by these very technological advancements resulted in those effectiveness gains, but was also accompanied by rather dramatic increases in unit fly-away costs. Since the advent of the jet fighter, the unit fly-away cost of each succeeding airplane has increased 1.7 to 2.7 times that of its predecessor. Same year dollars, same quantity of aircraft. That's a growth factor on the order, depending upon the airplane, of 20 to 40 times.

We should have done a better job marrying what we needed with what was possible without sacrificing capability or affordability. Then as we better understood our sciences and as our resulting technologies evolved, we could no longer independently pursue individual technologies or technical disciplines. A specific discipline had meaning or value only as it affected or interfaced

with other disciplines. As a consequence, the primary focus was shifted from system performance technologies to system integration processes. Integration processes, which initially were used to properly shape rational thinking in analysis, now dominate the insertion of technologies and design concepts. Certainly if a weapon system has not been properly integrated, its value and effectiveness is diminished. But likewise, if the functions which that weapon system are to perform are not completely and properly defined and characterized, the resulting form, no matter how well integrated, will likewise be of diminished effectiveness and value.

In closing, I'd like to say a word about the military-industrial relationship over the years. In my mind, during the subject developing years, the technical functions and operational units of the Air Force were very accessible to discuss technical problems and operational issues. The personal relationships and interfaces, in my mind, were quite effective. We, industry, got a better understanding of the scope, direction, and rationale of the technical thrust, the operational value, effectiveness, and limitations of fielded aircraft in their operational environment. The interface was quite active and quite open. I think each of us gained from the other's exchange. From this we got a broad base of readily available technologies and concepts which were both analytically and experimentally validated.

We would not be world leaders today in aircraft engines, turbine engines, if it weren't for the continuing efforts of the Air Force's propulsion directorate in the engine industry. And I can assure you that there would be no F-16 flying the skies worldwide if it weren't for the fly-by wire, relaxed static stability, high acceleration cockpit, and engine inlet technologies developed and experimentally validated through the joint efforts of the Wright Laboratory and industry in the late 1960s.

The period of fulfilling the vision has been replete with extraordinary technological advancements, most resulting in considerable progress, and as we've heard, some not. But by whatever measure of success during this period, there are lessons to be learned. Lessons that made the Air Force what it is today.

The Middle Age of the SAB

Dr. Robert G. Loewy

Hans has asked that we give illustrations of the fact that you can be judged by your failures as well as by your successes. I'm going to describe very briefly several SAB activities that fall in both categories. In addition, I'd like to talk about them in the sense that I see SAB tasks in the 1960s and 1970s as being thought of in three categories.

The first category is a group of tasks that were intended to convince the Air Force to undertake certain promising developments, usually far out, and seen as having a lot of risk associated with them. The second kind of task was to respond to an Air Force request to assess some advanced program already in the planning stages. The third was to evaluate the status of ongoing programs, usually at some critical juncture in that program where the Air Force wanted advice as to how it would go from there on.

The first of these examples is the study of supersonic fighters with vertical takeoff and landing capabilities (VTOL). The concept was that if you flew fast enough, the thrust you needed to overcome drag would be equal to or greater than the weight of the aircraft, and you could "get VTOL for free." Those were words that were used a lot. The second concept was that there was a square-cubed law for engine design. The square-cubed law for engine design said that the thrust was proportional to the area and therefore, the square of the dimensions. Additionally, the weight was proportional to the cube of the dimensions, that is, the volume. Therefore, the smaller the engine got, in principle the greater the thrust-to-weight ratio should be. This led to the idea that these fighters with supersonic capability and vertical takeoff and landing capability ought to have lots of little engines. In those days, the first cost and maintenance considerations weren't quite as prominent as they are today.

These studies went on, and there were debates about vectored thrust (as in the Harrier), or a series of lift-only engines, and completely separate power plants for cruise and high speed flight, or lift engines that tilted that could function both as lifting engines and thrusting engines in high speed flight. The debate was very active, and all these things were considered, and some of you may remember the initials USFRG. There was a vertical takeoff and landing supersonic fighter that was really thought of as one of the first international programs, because "US," of course, was United States, and "FRG" was Federal Republic of Germany.

In this case, the urging didn't really work and the Air Force never did build a fighter like that. As a matter of fact the only such aircraft in the western world that I'm aware of to date that's operational is the Harrier which, of course, uses the vector thrust. That was an example of an SAB activity which was far out and didn't come to fruition.

A second activity had to do with increasing range. This was looked at from a lot of viewpoints, one was to put boron in the fuel in the form of a slurry to increase the energy capacity per given volume or per given weight. Another which was carried farther was laminar flow control. It turned out that Northrop was given a contract by the Air Force to re-wing a Douglas bomber that had the initials RB-66. It was called the "Destroyer." Northrop took this swept wing, twin jet bomber, and they re-winged it, drilling thousands of tiny holes in the wings, and installed a pumping system for boundary layer air control, and this was flight tested.

It did show that drag was reduced and the laminar flow was preserved over a large part of the cord of the wing, but there were a lot of concerns with what would happen in the rain, and what would happen when bugs hit the holes. In all other respects, it was a successful project, but at that time the SAB got in the act, and there was no great fuel shortage—remember, this was in the 1960s. This begged the question, what do we need all that range for anyway? We have bases with allies. It turned out that the plans for the aircraft on the drawing board with laminar flow control would go a great deal farther than current aircraft but not far enough (halfway around the world and back) and so that program was stopped. Now whether you count that as an SAB success or a failure, I'm not sure. There have since been lots and lots of flight tests of laminar flow flight control, and if you speak to NASA and the aircraft industry now, you'll find that it's still going on. The bug problem is being handled by leading edge slats.

The third example has to do with composite materials. The idea of composite materials was brought to the SAB as one of the outgrowths of *Project Forecast*, and it was very exciting. People had found that boron fibers had tremendous strength in tension, and great stiffness as well. These were two major advantages, and predictions were being made by the SAB and others that you might save 30 or 40 percent of the structural weight of an aircraft if you made it all out of advanced composite materials.

The SAB actually conducted about three separate studies, each of which came out with its own report—one prior to 1965, one about 1968, and another somewhat later. The SAB told the Air Force to "Get on with it." There are a couple of major disadvantages with boron. The boron fibers were about the diameter of a human hair, but they were so stiff that you couldn't wrap them around any curvature of small radius. That was a great disadvantage for forming.

The second disadvantage was that it was pretty darned expensive stuff. The way you got the boron fibers was; in a vessel which was filled with boron trichloride gas, a substrate of tungsten was suspended in the center of the vessel. Remember, the boron was going to be the size of a human hair so the substrate was very much smaller. The tungsten was heated electrically, and when it got hot enough, the boron would deposit out of the boron trichloride gas onto the filament and you would get a boron fiber. As you can see, that's quite an expensive process. At one point the SAB even looked into evaluating whether or not there was enough tungsten in the whole world to build the aircraft we would like to out of composite materials.

But the SAB advised to get on with it anyway. There were other things coming along like graphite fibers using precursors like rayon, so it was coming from textile technology, and it was very much finer than boron. It could then be wrapped around small radii curvatures. Even though we didn't know what fiber was going to survive, we did know that the structural designers would be reluctant to use a material like this for which the failure modes were unknown. The SAB would convince the designers how to use this stuff. Of course they did find out. Delamination, fiber buckling, all these things turned out to be new failure modes, but modes that could be dealt with. As a result of the work of names like Standifer, Lovelace, Peterson, and with the help of the SAB, the rest is history.

In the last category, the SAB formed ad hoc committees in response to an Air Force request to look at a program with ongoing difficulties. The example—the C-5A. That's a personal experience for me because there was a point in the C-5A program where the Air Force said to

Lockheed, who had the contract to develop the aircraft, that there were enough problems that we wanted to see a "get well" program. So Lockheed put together a get well program.

I got a phone call from Guy Stever. He said, "There's a project that is of some importance to the Air Force and I'd like you to head the study." I said, "What is it?" He said, "It's too sensitive, I can't tell you what it's about. Just say whether you'll head it or not." I said, "Okay, I will." It turned out to be a study by the SAB of the "get well" plan of Lockheed for the C-5A.

Now I don't know whether you would categorize this as a success or a failure because the major result of that study (it involved people like Colt Ashley and Jimmy Marr) was the discovery that in the detailed design of the structure of the C-5A, Lockheed was using smaller margins of safety from materiel allowables than in any other aircraft up until that time. Our SAB report revealed that situation. I would like to think that the Air Force was poised and ready for the difficulties that later showed up as a result of that SAB study.

These four SAB activities are certainly only a small sample of the many and the great variety conducted in what, as we see it today, was the middle age of the SAB. I hope these are in some way representative of what went on back then.

A Remarkable Vision

General Lew Allen, Jr., USAF (Ret.)
with an introduction by Honorable Hans Mark

DR. MARK: Our final speaker for today is General Lew Allen. I met Lew for the first time, in 1958 when he was a major and I was working at Livermore. We had just gone through one of these things that we tried in those years that really didn't work out, and that was the ARGUS program. I remember that Lew did the theoretical work, and we actually made some of the experimental equipment at Livermore. We helped Jim Van Allen put a scintillation counter on Explorer IV. I remember putting that together in my own laboratory at the time. That was in 1957-58.

A few years later, there was a visit to Livermore by a congressman, and I think Edward Teller may have been at the meeting, but Johnny Foster was the Director. The congressman asked, "How do you judge a good laboratory?" He was interested in what had come out in the past, but he wanted to know how to judge the future. Johnny scratched his head and then he said, "You know, the best way to judge a laboratory is to go look at the junk yard. If the junk yard is too clean, then the laboratory isn't taking any risks, and if it's really too full of junk, you'll recognize that nothing is coming out. There's some middle where you need to have some junk in the junk yard, but not too much." ARGUS was one of the things that belonged in the junk yard.

Lew Allen is a distinguished military man, a distinguished figure in American technology. He's a graduate of West Point and has a Ph.D. from the University of Illinois. He served as head Director of the National Security Agency (NSA), as Vice Chief of Staff of the Air Force, and of course I had the great pleasure of working with him for two years when he served as Chief of Staff. After that we also had a nice association when he was Director of the Jet Propulsion Laboratory and a Vice President of the California Institute of Technology. It's a genuine pleasure for me to introduce General Lew Allen.

GENERAL ALLEN: It is remarkable that Arnold and Kármán's vision has served the Air Force so well for so long, especially since most of that period was a Cold War which they didn't really foresee.

One of the things that was in *Toward New Horizons* was an emphasis on the education of Air Force officers, and on a flexible assignment policy which would permit those officers to serve after a technical education not only in R&D activities, but throughout other assignments in the Air Force. I entered the Air Force in June of 1946, about coincident with the first SAB meeting (although I think the two weren't particularly related) and was clearly a beneficiary of the policies which the Air Force did indeed implement as a result of the *Toward New Horizons* recommendations.

I think those recommendations remain valid today. Particularly that technical education is extremely important for Air Force officers, and that the Air Force has been in the past and will continue to be in the future, very well served by a quite flexible assignment policy.

It was a particular treat for me following my retirement from the Air Force to be able to become the Director of the Jet Propulsion Laboratory (JPL), which was founded by Kármán. As a matter of fact, although it stretches a point a bit, he could be called the first Director of the Jet Propulsion Laboratory.

During the 1950s and early 1960s, I worked mostly in the field of nuclear weapons with special emphasis on high altitude detonations associated with ballistic missile defense. We created a laboratory in Albuquerque which was composed primarily of military scientists, somewhat unique among the Air Force laboratories at the time, and worked on a number of different projects. ARGUS was mentioned as one; Black Out, electromagnetic pulse phenomena; X-ray effects; neutron heating of the pit, were all subjects that were of considerable importance during that era and were in fact technical successes although the decision was made not to deploy a nuclear-based ballistic missile defense.

The SAB provided a very particular function to us then. That is, the nuclear panel provided a real critical review and quality control on a bunch of us who were very enthusiastic but lacking in experience. People such as the Latter brothers, Bob Lalivier, Dave Griggs, Ernie Martinelli, all reviewed our work periodically and with great vigor and in many cases the threat of their coming to review what we were doing had a remarkable clarifying effect on the quality of what we were undertaking at the time. I think that was a critical and important function of the SAB.

I really only wanted to make one other point, and that is that a meeting of this sort certainly fills me with a certain bit of nostalgia and a considerable bit of pride in having been at least some part of fulfilling the vision of Kármán and Arnold in building a high-tech Air Force which was a major factor in winning the Cold War, and whose high-tech emphasis was fully demonstrated and justified in the remarkable performance during Desert Storm. But I am a bit concerned that we may possibly be relics and less relevant than we would like to be for a new world which is really upon us.

The future is here now, and the Air Force and the SAB must not be captive to what is a great legacy. I encourage the SAB to accept the challenge of Secretary Widnall with vigor, and look at new vistas, and ask oneself not based on captivity with the past but on a recognition of what the future will really be, what the new vistas are. By doing this, they may create a vision for the Air Force which will serve as well as that remarkable vision of 50 years ago.

PANEL III

Extending the Vision

Dr. F. Robert Naka, Moderator

Lieutenant General Richard E. Hawley (in abstentia)

Dr. Robert W. Lucky

Dr. Michael I. Yarymovych

Professor Eugene E. Covert

Introduction

Dr. F. Robert Naka

During this panel discussion we're going to talk about the current role of the SAB given the demise of the Soviet Union, the Air Force response to declining defense dollars, the Air Force-industry response to increased world conflicts, and ready availability of the latest technology and long term trends in research and development.

I have talked to some historians about the demise of the Soviet Union and how it came about. It's pretty clear now that the Soviet Union simply ran out of money. I used to marvel that they could continue to invest as much of their gross domestic product as they seemed to have been doing. The usual public view of the gradual demise perhaps starts on April 26, 1986, with the explosion of the Chernobyl nuclear powered electric power plant. The usual person on the street said, "Hmm, that's interesting." But had the Soviet Union continued in its normal process, we would have heard nothing about it. That is to say, they wouldn't have admitted anything. The nuclear cloud would have gone over Scandinavia, it would have been measured, there would have been outcries. You may have heard something from Ukraine where the plant was located, and the cloud would have drifted slowly eastward, and we would have had some more measurements there.

The public, perhaps, would have noticed that in February of 1989 the Soviets withdrew from Afghanistan. Finally, the most dramatic of all, in November of 1989, the Berlin Wall was destroyed.

The historians point out that President Gorbachev was afraid after the explosion of the Chernobyl plant that it could be the cause of World War III. We won't know that, of course, until after the death of President Gorbachev and we actually get some hard information, but that's the opinion of the historians.

Gorbachev came into power in the spring of 1985. He was fifty-four years old. He made a speech the following month in which he stated that changes were due, and the Politburo expected that they would be minor and cosmetic. Instead, when the elections were held in 1989, the changes were significant. In between, there were discussions with President Reagan about compromises that the Soviet Union would be willing to make on some of these diplomatic clashes that occurred. We noted that in October of 1989 we had the meeting at Reykjavik where the press said this is going to be a very friendly meeting. That turned out to be total failure because Gorbachev wanted President Reagan to stop the strategic defense initiative (SDI) program, and our President refused. A month or so later we saw the destruction of the Berlin Wall.

How to Win the Numbers Game

Dr. F. Robert Naka for Lieutenant General Richard E. Hawley

One of the things I requested of General Hawley when I learned of his dilemma (General Hawley was called away unexpectedly at the last minute) was to give me his talking paper, which he did. The point he wanted to make was that recent history is not too different from what happened after World War II. We did have an expansion that was initiated by President Reagan, and it could be that this expansion did lead to an impossible situation for the Soviet Union and ultimately led to her collapse.

I'd like to thank Lew Allen for setting up our panel quite nicely by what he said, because that's really the subject of our discussion this afternoon. Kármán once wrote to General Hoyt Vandenberg,

"The Air Force is the arm which promises to play the major role in any war which we can now foresee. Unless that war takes place at once or within a very few years, we must fight it not with the weapons we have today, but with the weapons which research and development can put into our hands tomorrow. In fact our margin over potential enemies lies predominantly in technical superiority which we can now enjoy and must maintain. It would be very dangerous for us to suppose that we can remain secure by making technical progress at anything less than the maximum rate of advance we can achieve. The prominent role of the Air Force in preserving the national security cannot be long maintained if the Air Force falls behind in its research and development."

What do we face today? We face a lower perceived threat. There is a sharp decline in military budgets, a sharp decline in manpower and equipment. Budget, rather than the threat, drives the force structure. When budget cuts drive R&D, we have a danger of mortgaging our future.

I'd like to throw out some numbers. In 1945, the Army Air Forces had 2,300,000 people. In 1949 the Air Force had 420,000. In 1985, we had about 600,000 personnel. Today we're down to 400,000. Back in 1945, we had 154,000 pilots. By 1949 there were roughly 29,000. In 1985, we had a little over 24,000 pilots. Today we're down to about 15,000 pilots.

Next I will look at the number of aircraft. This will astonish you. In 1945, we had about 68,000 aircraft. In 1949, that number was down to 20,600. In 1985 we had about 9,500 aircraft. Today, that number is under 5,000.

The diminishing numbers and proportion are roughly the same, and you'll see that in the budget also. As a percentage of the gross national product, in 1945 the budget was 5.3 percent—the numbers were in the hundred millions. The RDT&E portion was 0.7 percent. In 1949, the numbers correspondingly were two percent and one-tenth of a percent. In 1985, we were at about half the 1945 number. In 1985 we were at at 2.1 percent, and the RDT&E was about 0.3 percent. What's happened today is we've dropped the percentage of the gross national product to 1.24 percent and RDT&E has declined to about two-thirds of that, or about two percent. That's a substantial decline, and we have to be very careful that we don't mortgage the future.

Kármán also once said, "Leadership in research and development cannot be legislated or proclaimed. It must be earned. One important fact must be kept in mind. Research and development activities cannot be brought to full effectiveness without making corresponding sacrifices elsewhere in the Air Force. A decision to correct some of the deficiencies in the present research and development situation will be valueless unless it is implemented in terms of competent men, money, and effort, and such men, money and effort must come from a fixed, possibly even declining total Air Force allocation."

He went on to write, "It is my feeling and that of the committee that the effectiveness of research and development is so uniquely important to the continued supremacy of the Air Force and the continued security of the nation, that the necessary sacrifices must be made. Steps should be taken to ensure that the process of successive cuts and the economy measures within the Air Force do not form a growing avalanche which hits research and development with its maximum impulse, destroying essential agencies and projects of this vital part of the Air Force organization."

I hope I've handled Gen. Hawley's remarks as well as he might have wanted me to.

"Gentlemen, the Plane Must Come Back!"

Dr. Robert W. Lucky

It's an honor and a great pleasure to be here at this unique and "once in a lifetime" gathering. This group will never be gathered like this again, I'm sure. It's certainly a pleasure to share this with everybody.

There's been a lot of talk this morning about what we've given the Air Force, but I'd just like to mention in passing that the Air Force has given us something, too. That is, the ability to work on meaningful problems with very good people and compatriots from other disciplines and other companies. It's a wonderful, wonderful group. I certainly have enjoyed it. I know everyone here has. It's a very wonderful and unique quality, and I think we should recognize that. (Applause)

I want to talk about some trends in industry that have relevance to the Air Force now and in the near future. I have a small list that I'll go through, but I want to spend most of my time just giving two personal anecdotes that illustrate the first item on my list; the trend toward information technology; the trend of interest in the virtual world, in software, and in the use of information, and at the expense of interests in the physical world.

Let me start with two personal anecdotes. They both relate to the SAB. They illustrate, in the extreme, both ends of this spectrum. When I first became a member of the SAB back in the early 1970s, Ivan Getting was kind enough to invite me to join a summer study that he was doing on the Long Range Combat Aircraft (LRCA). It was a very large study, and I'm sure there were a number of people in this room who were involved in it. The first meeting was in the Pentagon and I was a very junior member of the group. My particular memory was that early on, this was our first meeting, someone at the meeting, I don't recall who it was, said, "Look, we're going to have to get this thing through Congress, this new bomber, and we're living in an era where human life is sacrosanct. If Congress is going to approve it we're going to have to show our concern for human life. I have this thought that perhaps the crew should be in a capsule, and if the plane gets in trouble over enemy territory, the capsule can drop out and fly home so that the crew is protected."

There was quiet for awhile. Frankly, I thought this was a dumb idea. I hope there's nobody here that suggested the idea, but there could have been. But as a junior member I wasn't going to say anything. It was quiet for awhile, and Ivan turned to this little old man next to me and said, "Jimmy, what do you think of that?"

I had never met Jimmy Doolittle before and I certainly gained a great respect for the man and his wisdom. But what Jimmy said was, "In the Second World War whenever we shot down a Japanese airplane, the important thing was that they had one less pilot. They could make many of these airplanes but they had a limited capability to produce pilots, so we diminished their warfighting capability by destroying the pilot. Today we have many pilots. The Soviet Union has many pilots. But the entire resources of our nation can only make a handful of these airplanes. Gentlemen, the plane must come back."

There's a great deal of wisdom and prophecy in that. I put this in the context that the projection of might is an economic factor. We went through periods where it was a matter of force, where it was a matter of great science, but somehow it would turn to the economic might of a nation. What happened in that LRCA study was it reinvented, or invented independently, stealth technology, and the outcome was a recommendation for a project that became the B-2. As we know, the cost of the B-2 is toward the better part of a billion dollars, and today we're arguing whether we can afford any more of these airplanes. Therefore, I think Jimmy's words were prophetic. This is an example of the power of the big, expensive thing.

As it turned out, much to my shock (and that of many people), we won the Cold War and we won it through economic might as has been said several times this morning. We have to recognize how important that factor is in the world today, particularly in projection.

Let me turn from the big, expensive thing to the small nothingness at the other end of the extreme. Let's fast forward to 1990 and another SAB study. This time we're studying electronic countermeasures. One of our subcommittees was looking at how to take down the enemy's air defense network.

As an example of this, I have a report in front of me on the Iraqi network. This was from long before the Gulf War had occurred, so it's totally coincidental. I was studying the communication network that links together the radars in the Iraqi network. I was thinking to myself, "this damn thing is hard to bring down." We postulated where you would have to bomb, what nodes would have to be taken out, and what special forces would have to be put in to cut links. The diversity of the network made it very, very hard to do anything with.

Coincidentally, January 15, 1990, the unthinkable happened in the United States. The AT&T network went down. You could not make a telephone call across the country January 15, 1990. It was unthinkable. AT&T had never prepared for such a contingency because they hadn't thought of it.

We have a network control center in Bedminster, New Jersey. Most of us have been to the Cheyenne-like, NORAD center there. It looks a little like that on a somewhat smaller scale (Most would say the opposite. Most have been to the Bedminster Center, but Cheyenne looks like that, only bigger. On this crowd I have to use the reverse). The difference is, at the AT&T center there are no generals sitting around because they never envisioned the need to make a decision based on what might happen. As the map went red, as every link went down across the country, there was no one to make a decision, chaos reigned, and it was many hours—only through luck and chaos—the network was put back on its feet. In fact, there were many wild ideas being considered.

One I particularly liked. One young supervisor suggested that we reboot the network. Now semantically that's very interesting, because "reboot" implies that it has once been "booted." You can imagine in your mind, there's a big knife switch on the wall that says "network - on/off." So no one had ever turned the network on, every in history, and it was not known how it could be done.

Of course, AT&T has generals sitting around and they learned a lot that day. But in 1990, I was on a committee which looked at what went wrong; why the AT&T network went down.

So on one day I'd be working for AT&T and figuring out how to keep a network up; the next day I'd be working for Air Force on how to take a network down.

The juxtaposition was very interesting. On the days I was working with the Air Force, we worried about what to bomb. I envisioned weapons filling the air and explosions. But what took the AT&T network down was one line of code. One line of code, weighing nothing, occupying no space, at almost no cost, took down the entire United States network. You could bomb this country all you wanted to and still make calls across the country, the network is that robust. But one line of information, one bit of knowledge, took the network down. The juxtaposition of these two examples made it very clear to me the power of information in this world.

More and more at management meetings today, talk centers around the competitive advantage in industry, and everyone looks for that competitive advantage, and the Air Force must also. It lies in industry's use of information technology. That is where the pendulum has swung in industry and that is where it's also swinging in the Air Force. Ed Feigenbaum, the new Chief Scientist, is the first computer scientist to fill that position in the Air Force and it's a sign of the times.

That's just the first, and I just want to go through the rest of my list rather quickly. Environmental factors, and certainly the biggest that all of us realize is globalization of everything. The world has changed so much. Back in the early 1960s when I was at Bell Labs, we were it. This was the most important place in the scientific world in my field. There wasn't any other place. But today there are many such places. Technology has spread throughout the world.

I talked about the importance of computer technology, and that technology is generally available. You can go in the stores and buy cheap computers everywhere, absolutely as good as what we've got. You can buy software everywhere. It has diffused throughout the world. Things that we once considered such precious secrets are now available everywhere.

You're going to be able to go into the equivalent of "Egghead Software" in any country and buy unbreakable codes for $39. Now we spent fortunes in developing cryptology, offensive and defensive, in all the wars that we fought. But now for everyone, the genie is out of the bottle. While we wrestle in this country with trying to figure out how to deny citizens the use of this technology, it is spreading throughout the world, and those codes will be available.

Additionally, we thought we could lock in GPS uses for the military, but people are finding very sophisticated ways to use it without knowing the access codes. That technology is available to the world. Everyone will have SATCOM. If Bill Gates and Craig McCaw have their way, they'll have broad band satellite communication available to anyone anywhere throughout the world. Internet, growing at 100 percent per year, links the entire world and is available to everybody.

The problem is, what is unique to us in this country? Why are we special? Why are we a special place? I pose this as a question that I'm not going to answer right now. I think it's a problem that requires examination in the forthcoming study by the SAB. How we can be special in this world of information that's being created?

At the same time twenty or thirty years ago, our scientific rank was absolutely preeminent. That may still be true, but it's no longer unquestionable. It's arguable whether we are the best in

the world. At the same time it's definitely true that there is ever-decreasing spending on industrial research in this country. That is absolutely true. I just came from a meeting of the Industrial Research Institute. Some 88 percent of the companies say they're spending less on research this year than last year. It is happening. We may no longer be number one, and are headed downward. Economically we were once totally preeminent. That also is now being questioned.

Furthermore, the leverage of the Department of Defense through all this is certainly much less than it was before. Twenty-five years ago the DoD could specify what it wanted and have it done. But it is no longer special either. We've gone through such evolutions as well. "ADA is going to be it, that will be the language." But the market said, "Hey, forget it. GOSSIP is going to be the protocol." The market says, "Sorry, but we like TCPIP. You're wasting your money if you do anything else." We are no longer the dog that wags the tail, but the tail that wags the dog, and we have to figure out how to work in that kind of a new world; how to ride the wave of commercial technology. That's what you have to do. You have to see where the wave is going and you have to get on it. You cannot create the wave yourself.

In industry during this time there's been this shift in management science toward process, toward quality. An emphasis on managerial science as being the important factor in distinguishing one industry from another. This is also important if you want to be preeminent in the Air Force, to be able to use management systems. This is a management problem. During the same period, the large corporations in the United States have had big problems. The Air Force is a large corporation. The vitality in America has been in the small entrepreneurial companies. The Air Force is not one of those.

These are some of the trends in industry that I think affect the environment that today's Air Force and the Air Force in the near future have to contend with.

Data We Have, Information We Need

Dr. Michael I. Yarymovych

The Secretary really gave us a tall order. One of the problems with doing long term studies is to be heard and to be listened to. I remember in *New Horizons II*, 1975, the major conclusion was: the Air Force is entering an era of computational plenty. In 1975, that was an outrageous statement and it was buried. What are we hearing today? "Every kid's got it." This will create, this has created a changing operational environment.

The world that we live in is changing. Most likely the Air Force in the future, most of the time, will be operating as part of an international force, not just alone. We may not have foreign bases. We will need rapid power projection forces. And more importantly, there is always going to be somebody ahead of us on the beach head. Do you know who that is? CNN. They'll be there taking your picture as you're coming on board and as you stumble. The pressure is going to be to win and win quickly and get out of there, and to suffer no casualties. Also, it will be necessary to minimize casualties on the other side.

To accomplish all of this we'll have a much smaller number of flying platforms which means that there will be more pressures. Not just more expensive platforms, but pressures. Therefore, the platforms will need to be used much more effectively. The threats to those platforms and to our presence will be coming from everywhere. As a matter of fact, to take Bob Lucky's thought further, we can look forward to the world of warfare with commercial technology. Commercial wars. I don't mean wars with commerce, but done with commercial technology. GPS, of course, is proliferating everywhere. It is a force multiplier and now it's becoming a force multiplier for everybody else as well.

Everybody's got that computer. Everybody is going to get GPS. Everybody has global communications. And a two-bit dictator can give us a very hard time. Why? Because they, whoever they are, can use commercial technology which is rapidly increasing, doubling every 18 months or two years.

What are we doing? We are stuck with a procurement system that guarantees everything to be a museum piece. Everything we produce will be ten years old, at least, if you are lucky. Yes, we recognize we ought to do something. For that matter, yesterday we heard there are some actions being taken, some of it has to be legislative, because a lot of our paralysis is built into the legislation. So that will take awhile.

But one more important thing, the third step is that we have to change our culture. Those cultural changes will be the slowest. I really expect that we should look forward to a paradigm shift. It's a much over-used word, but I really mean it. We have to recognize the need for an operational based vision on a doctrine of information-based warfare. It's no longer based on the particular flying platform that you happen to have, because it provides knowledge, and knowledge is power. It's the largest force multiplier, and it doesn't stand alone.

We have to prepare the battlefield, and we've done that. We did that during Desert Shield. It took us awhile, but we prepared the battlefield. And we actually supported the warfighter during that brief war: Desert Storm. We actually say that this was the first information war. It

was very effectively used. The objective in information war is to create a mismatch between us and the enemy, and operate inside the enemy's response cycle, the enemy's information cycle.

How do you do this? This will come from the integration of a wide array of capabilities. We're very proud of how GPS worked. We're also very proud of how multi-spectral imagery was used, how signal intelligence was used in various ways, and how sometimes weather information was used (although that was a little slow). But it all came down a separate stovepipe. It all came down to the ground and was managed with great effort.

We have to disrupt and destroy the enemy's C^3I capability, and we are pretty good at that. We've done that. We've proved that. What I'm concerned about is this. Can we protect ourselves against the enemy disrupting our C^3I capability? That is the difficult task, technology is here.

Clearly the answer is not to bring down the curtain on information transfer, having some exorbitant and draconian laws locking us in, because as Bob Lucky says, it's out, it's all over the world, and the world is moving.

There is still some advantage that we can maintain. That is the use of space-based resources, where space-based information can be used in an integrated sense. We have to provide routine "space" to the warfighter. This is not, as some have suggested, piping satellite data directly to the cockpit. I would like to make a very important distinction between the huge mass of data that's available and useful information that the pilot needs. Data we have, it is *information* we haven't worked on very much.

It has got to be just the right information at the right time during all weather conditions to provide situational awareness and this may be, clearly, an information overload.

How do you manage this? It must be credible to the user. That pilot is not going to trust some analyst in Washington, D.C., no matter how good he is, to tell him where he's going to put his life on the line. He wants to hear it from his commander right there down on the field. The commander is going to be the guy that's going to fly the next day and try to survive just as well.

I have this vision—we all share it, of course—that there is a display in the cockpit. A picture, an image that was taken by a satellite on some nice day of the region. It is digitized, of course, and it will change with aspect, and it contains body-mounted coordinates, so the pilot always sees out the window of what is being displayed. That picture is now annotated with the latest synthetic aperture radar that gave him the situation of the latest hour ago. He will not be able to decipher a SAR image, so it has to be converted to his visual senses. And, most importantly, this picture has to be annotated with secondary data about particular location of the defenses that he's got to circumvent and of the target that he's got to attack.

How do you do this? The idea is to create a unified battlefield. It's not just for the pilot. The same thing goes for the Army warfighter. He's got to see the same picture that's particularized for him. I can see a system of small distributed satellites that provide the latest SAR information, that are tasked by the local commander to look at very specific areas. He doesn't really need a wide field of view picture of the entire country of Iraq at any particular moment. That is necessary for other intelligence purposes, but for these purposes, you want the specific things, and you want this coming rapidly, right now, timely.

This can be done. It's affordable, as we talked about in several of our studies. To do this we have to have pre-positioned objects in space so that you can train as you fight and fight as you train. You don't do this as an afterthought after some kind of a war starts. You have to be able to expand the constellation in a couple of weeks, which is affordable and doable.

So in the end, I think the vision that we should be looking for is information based warfare that is a major change in our way of looking and thinking. It has to be global, because you don't know where you're going to be next time. It has to be routine so that you can operate with it all the time. It has to be timely. Central processing is not going to work. It's like the days of the large mainframe computers, the distributed computers that we have now. It has to be reliable but, more importantly, it has to be trusted. So the editing, the information integration that's being done, has to be done by people who are part of the fighting unit. It has to be user friendly so that a pilot in one airplane, the next airplane, a third airplane, even different kinds of airplanes can handle it the same way. Yet it has to be just enough and not too much, because we know we have tons of data. We're going to need useful information. Of course it has to be survivable and affordable.

That's a task that I think we must undertake, and the challenge we have to face as we proceed with the assignment that was given to us by the Secretary.

Cognitive Research and the SAB

Professor Eugene E. Covert

It's a privilege to be here and to talk to you, and it's always, in my view, been a privilege to be able to work with the Air Force in various capacities.

I think the Air Force has one remarkable attribute that perhaps you've thought about but not articulated, and that is that they take a bunch of strangers from the outside and bring them in and talk to them about the dirty laundry that they have. I think, in a sense, it's this sort of trust and integrity that the Board has that's very important to maintain, and I'm sure it will be maintained in the future.

I've almost completely suppressed the idea that I should deal with the long term here, perhaps 75 years or longer ahead, because that will ensure that there's no one that's here that's going to be alive and point out where I was wrong in what I predicted for the future. I shall press on.

The other thing I had planned to do was to talk about the view of science and technology in the Air Force as being divided into four or five categories, and then deal with the fact that such a reductionist viewpoint is no longer appropriate. That we really were very good at looking at systems, but I don't think we've really considered the fact that research as is needed for the Air Force is becoming more and more as a system.

But as I sat here and listened to the marvels of modern communication systems and computers and the consequences that follow from these and the value of space observation systems that Mike described, several thoughts passed through my mind and I thought I might ventilate those as well.

The first is a matter of who gets what data. So far we've not done this very well and most management information systems probably fail as much in the breach as they do to solve the problems they were set up to solve. There are a number of reasons why they haven't lived up to their promises, and I don't think that I want to discuss that here. Probably because I'm not knowledgeable enough and I don't want to air too many prejudices.

The second thought that passed through my mind is how to get this data to the right person and how to convert this data into information that allows the person to make the best decision (whatever 'best' means under a given set of circumstances). I think that's another thing that is going to be a real challenge. In this regard, in comparison to a lot of modern technologies, our ability to present data is probably in the bronze age.

I don't think we've developed at all enough resources or allocated enough resources to this particular problem, and I will make a few remarks later on about the importance of brain and cognitive science to help deal with this problem. I will apply a term that is used here and there called cognitive engineering. The purpose of cognitive engineering is to grapple with the issues of the man/machine interface, and in the long run, automate systems in a way that allows people to do what people do best. As opposed to automating what you can, automate and expect the poor people to come up with whatever they need to do.

The third is equally simple, assuming that we knew the answers to the first two questions. The third question is: will the Air Force be able to afford to deal with these systems? I guess I'm not convinced that this issue has been totally solved, either, and it may involve a complex, long term planning issue. It may also require an enormous amount of discipline to stick to the plan once it is made.

I think I can give an example of what I mean by this latter point. As I understand avionics in the modern airplane, they really consist of a bunch of sensors that provide information onto a database of some kind. It will probably be optical in the future. All of these pulses travel around, and every so often there's a computer that recognizes what something has said to it, and it, in turn, then acts on it. If the sensor is a radio, for example, the pulses get converted into a message into the headset. The issue is to how to upgrade modern equipment and incorporate this in a rational way. Based on information that I've been told, the most expensive way to do this is in the field in a hurry. The least expensive way of doing this is to plan to do it over two or three PDM cycles. That is a 10 to 15 year period. It seems to me one of the most difficult challenges that the Air Force faces at this point is what kind of a strategy to adopt to incorporate these changes and, as I mentioned before, how to incorporate these changes and have discipline so that what was planned to do in 1998 is in fact carried out in 2008.

We can see an example of this right now in terms of the KC-135, for example, an airplane that is expected to be in service in the year 2040. Incidentally, the average age then will be about 60 years old. Now they're replacing the wire harnesses. Why not replace it with a database and put a chip at either end of the database so that it fits in with the analog signals that are available. It seems to me that this makes a certain amount of sense, but again, perhaps logic is not the overwhelming aspect of economics at this point.

I think there are other issues that are equally complex and demanding that we need to deal with. I'll go back and suggest that there are, at the present time, five classes of research that the S&T community looks at. Fundamental research, research to improve weapon system performance, research to improve the design and manufacturing processes, research to focus on component improvement, and finally, last but certainly not least, is research focused on service life extension.

The general feeling that one gets, and I'm sure you all don't believe this, but there is not an orderly progression from 6-1 to 6-2 to 6-3, etc. In fact, it's quite possible that in trying to deal with service life extension and trying to decide where corrosion is between two pieces of metal without having to take them apart, that this will stimulate a certain amount of basic research of one kind or another. There's got to be continuous feedback and continuous feed forward of this information. The other aspect of this is that there's a lot of knowledge around here, and part of the knowledge is how to apply it to a practical situation. Again, an example might be helpful. I can remember when lasers were first invented and a lot of people suggested that laser cutting and trimming is probably the way to go. It turns out that wasn't quite the case, and the reason was that we didn't have the computational power to be able to guide the laser appropriately. Computational power is available now, and the excuse is, we don't know how big the heat affected zone is so we don't know the materials property in this zone so we don't want to use it. So there are other things that impede the way of adopting modern technology. In the mean time,

we all know of many applications of lasers that none of us ever thought about when they first came along.

While fundamental research in these various forms cannot be ignored, I think part of the solution is to create an environment where people are willing to take chances and try to use the outcome of this fundamental research. Secondly, I think it's very important to keep the broader view of the fundamental research, the research to improve component technology, and to look at this as a system that's needed to support an Air Force with a smaller force structure and with less money, but at the same time, will be expected to do the things it did in the past with the larger force structure.

I mentioned briefly the idea of brain cognitive science. I want to make a couple of comments about this. The idea here is to help people get data presented to them in the most effective way. This is not an obvious problem, and it's not a trivial one. I saw yesterday a new all-electronic cockpit display system and the air speed is indicated digitally. In this particular example it was three digits—three-zero-zero knots. I'm not sure for most circumstances the pilot really cares whether he's at 300 knots or 301 knots or even 310 knots. I think what the pilot needs is some indication that all is well, and this might be a green hand overlaying a red hand or something like that. We have to think about the consideration and how this information is going to be used.

Another thing we need to do to try to use our money most effectively is to use simulators in the most effective way. A great deal of advances have been made here, and the opportunities here are very great to save money, and to allow people to practice those things they can practice in a simulator over and over again, without getting three shots in a flight, as opposed to 16 tries in a simulator in the same time.

You all know this is the low cost end of a product cycle, and is the place where a great deal of investment is worthwhile.

PANEL IV

Enabling the Vision

Dr. Gene H. McCall, Moderator

Dr. Peter C. Bishop

Colonel John A. Warden, III, USAF

Dr. Robert M. White

Dr. Robert J. Hermann

Closing Remarks: Dr. Gene H. McCall

Speaking as a Futurist...

Dr. Peter C. Bishop
with an introduction by Dr. Gene H. McCall

DR. McCALL: The subject of this panel is enabling the vision to guess at the future. It is undoubtedly inaccurate. Those on the panel have the advantage that we won't find if they are right or wrong until it's too late.

Another thing we're doing on this panel is to bring in a few people who have not historically been associated with the SAB. Our first speaker will be Dr. Peter Bishop, who is chair of the Department of Future Studies at the University of Houston. Dr. Bishop has made a career, at least recently, of thinking and talking about the future and discussing it with students, so I think you'll all be interested in what he has to say.

DR. BISHOP: I am the consummate outsider in this group, and it has been an enjoyable day listening to the history and the current issues confronting the SAB.

I actually wondered why I was selected as a speaker other than being a futurist, and I realize now there is a hidden motive to this. Air Force intelligence had determined a long time ago that the fall meeting between General Arnold and Theodore von Kármán took place at LaGuardia Airport, just about two months before I was born, and just about 20 miles from my parents' house. So I think I was probably closer to that meeting than anybody else in the room. (Laughter) Unfortunately, I don't remember much of that time so I can't report on that meeting at all, but it was an historic event, and has obviously led to great, great things here.

I'm one of the few people in the world who's not afraid to call himself a futurist. When I first started calling myself that it was not a very nice term. It's now almost to the level of "neutral." Working close to the year 2000 may be where it becomes even "valuable." The futurist is the person who is the classic outsider, the person on the periphery.

I don't know much about Air Force lore, but I think of myself as the wingman, watching your back as you guide your organization forward. Since receiving this assignment, I've been interested in the SAB because it's a success story of enormous proportions. Two people with vision, complimentary in many ways, create something, and that's something that we in the futures business are always trying to show and trying to encourage people to do. But success, like the SAB, is a rare commodity.

Being interested in the future, however, I'm also interested in the future of the SAB and whether or not it is prepared for this next century. Since I know very little about it, I can speak freely, unconstrained by the facts. Yet I'd like to share with you a principle that we use in future studies. That principle is actually a paraphrase of what General Allen said this morning. Those formulas that were successful in the past are not guaranteed, and often times are not successful for the future. Organization after organization says, "we now have the way it's supposed to be done," realizing that it was done that way very successfully, but it will not necessarily be so in the future.

Is the SAB's formula for success linking the best minds in the scientific community with the strategy thinkers in the Air Force? Is that the synergy that has served both parties handsomely over fifty years? Will this be the right formula for the future?

I'd like to ask you a set of questions. These questions embody a little bit about a world which is very much changed from the one that we live in today. This is really a test of your imagination, not necessarily of your scientific or political intellect. The first question. Would you be surprised if biotechnology became the strategy of choice? Not only for treating disease in the future, but also for producing most of the food, energy, and raw materials, thereby replacing agriculture, mining, and the petrochemical industry as we know it today?

The story goes like this. We may be at the same stage in the development of the biological society that we were for the information society fifty years ago when the SAB was formed. One computer as big as this auditorium, programs that looked like telephone switchboards, rotary telephones, no television. But during that period we also created the basic science and technology that today forms the basis of a new economy—one that was described very clearly in the last panel.

The next industrial revolution could rest on our ability to do the same with biology. To program microorganisms to specification with the same delicacy that we use to lay down millions of lines on a quarter inch semiconductor. If so, we will have placed the process of life under human control and replaced natural selection with human selection for all species, including our own. That future society will use living things for its purpose through DNA on demand, just as we use mechanical things today. Just as surely as the physical environment is not the same after industrialism, so life on earth will never be the same after harnessing the genie of biological manipulation.

Question number two. Would you be surprised if the United Nations became an independent-minded organization again, tackling the issues of poverty, illness, and malnutrition which they believe is caused by the distribution of wealth in the world? That story goes like this.

The U.N. General Assembly becomes the dominant UN organization once more, taking that role from the Security Council. Tempers around the world have cooled. The tribes that went to war after the Cold War now realize that they have more to gain by working together than by fighting each other. The newly developing nations, unsatisfied with their rates of growth and envious of the economic share still enjoyed by the industrial powers, moved to control the UN with increased contributions in return for increased power. The north/south debate is conducted in a forum that is not friendly to the U.S. or to the other industrial nations. The U.S. may have to agree to some painful realignments or leave the community of nations altogether.

Question number three. Would you be surprised if multinational corporations became the major actors of the global society, wresting that role from the nation state? The sovereign nation is a creation of the early industrial society, and may become unnecessary as industrialism matures into an integrated global economy. The nation served the purposes of industrialism by bringing peace and order to the regions under its control, defending those regions against foreign aggression, and providing education and other social services to a work force bound for the factories and the bureaucracies. When land and territory are no longer important for business,

national sovereignty may become more a burden than a blessing. As a result, nations might place less emphasis on control and more emphasis on being attractive to the corporations and their technology, their capital, their facilities, and their jobs. The businesses, freed from the shackles of domestic regulation, may roam free across the globe to make money in more effective ways. The last time capitalism was this free was 1880 to 1900, a period of some of its greatest abuses. The financial world is already enjoying such freedom, essentially unfettered by any type of domestic regulation, and communications is not far behind.

Would you be surprised if free societies failed, just like communist societies did? The value of liberty is the most cherished value of our society. Along with security, it is the basis of public decisions. But with liberty so enthroned, can any other public values be advanced? How can any official promote one set of values when they may conflict with someone else's?

Freedom from political constraint was born in the American Revolution, but the Declaration of Independence and the Constitution were written in a society where the family, the community, the school, and the church socialized people into a coherent value system. But where are those institutions today? The family torn asunder by economic forces; the community destroyed by television; the school unable to promote values in a divided community; the church officially banned as an agent of public life. If the protection from totalitarian threats was the guiding principle of national policy in the 20th century, and that threat is withdrawn, what are we here for except to let everyone do as they please? Is that enough on which to base a society?

The fifth and last question. Would you be surprised if the world's economy experienced a boom after 2000 that was bigger than the expansion during the 1950's and 1960's? That story goes like this.

Economies grow because of increases in productivity. The same people offering more goods and services to each other. But the increases in productivity are not linear. They come in spurts. The railroad provided one spurt; electricity another. Petroleum provided the latest spurt and produced the energy society, the society we grew up in. Since 1920, the largest industries in the U.S. have grown from the barrel of oil—the oil industry itself, the automobile industry, airline manufacturers, and the airlines themselves, and the petrochemical industries. Listen to the names of those: Exxon and General Motors, DuPont, McDonnell/Douglas, American Airlines, Ford, Toyota—all based upon the barrel of oil.

The twilight of the energy society began in 1973 when we realized that this commodity would not always be abundant and cheap. We still have plenty of it, more today than ever, but we are not counting on it for economic growth. In fact, the companies that succeeded in the energy society are exactly the ones that are downsizing as we leave that society behind.

We now look to the computer and communication industries as the basis of the new society. Companies like Intel, Microsoft, AT&T, Time-Warner, IBM and Apple are destined to be the giant corporations over the next 25 years. But despite hundreds of billions in investment, we're not there yet. Computers are still too hard to use and don't really do what we need them to. The fiber cable is not all laid; the wireless band width is still too narrow. But when the infrastructure does get settled, we may be able to squeeze waste from the system and produce goods and services at a fraction of their current cost, as well as provide information and services undreamed of today. There it is, productivity.

Our current problems, then, are the result of the transition from the energy society to the information society, not a failure of capitalism or industrialism itself.

Are you surprised? I hope so. Should you be surprised? No. Surprise is the result of incorrect expectations; events taking place that we had not anticipated. The official future causes surprise because those who believe it will most certainly be wrong. The antidote to surprise is the scenarios like I've described. Stories about the future. They are not predictions. They may never come true. But if they are credible, and I've tried to make them so, then prudent people act as though they might come true. That is, they prepare for them.

My stories are not military scenarios. They are not even scientific. Rather, I am advancing a thesis like the ones advanced by General Arnold and Dr. von Kármán. Namely, that military advisers must create links and gather information from all disciplines—not just science and engineering—as they envision their future. General Arnold saw the interconnection between science and the military, but now the interconnections between economics and the military, between technology and the environment, between social values and national security have become tight. So tight that when any of these institutions changes, the military mission and the military means changes as well. Our security as a people is now wrapped up in the intricacies of these forces. Secretary Perry made exactly those comments this morning concerning when and how to use military force. That's not the job of the SAB, but anticipating the force that will be available to future Secretaries of Defense is. The type of force is dependent on the type of environment in which it is used.

One future for the SAB, then, is to begin to tell itself stories. Not just about advances in science and technology, but also about the larger political, economic, social, and ecological context that shapes the future of the military and science alike. The interconnected world of the future cannot be understood by dividing it into disciplines. Somebody needs to be looking at the big picture.

In 1944, the Air Force needed a good pair of headlights to see down the road and the SAB provided that service admirably. The road used to be fairly straight, and the headlights only needed to point in one direction. But now the road has turned narrow and torturous. Unexpected obstacles pop out of the dark. We need peripheral vision, like a good pilot scanning the air space or the lookout on the ships of old. It was Secretary Widnall's image of the study that she has commissioned, *New World Vistas*. She used the concept of a panorama, a wide view of the future—not a narrow one—and challenged the SAB to look as widely as possible.

Perhaps the SAB of the future can see then not only far, which it has done very well, but also wide, and discern the shape of emerging change. If it does that, I certainly wish it the greatest of success and guarantee as a result, it will not be surprised.

The Information Revolution and the Future Air Force

Colonel John A. Warden, III, USAF

My charge for today was to try to bring together a handful of complex ideas and, based on those complex ideas, see if we can put some kind of a very rough "straw man" together which may be of some value to the Scientific Advisory Board as it begins its second half century of existence. I would like to start out by saying that this second half century that the Board is facing is taking place in what almost certainly is the most exciting, opportunity filled era in the history of the country, and I would argue, in the history of the world itself.

From the standpoint of the United States, this means there is a once-in-a-millennia opportunity to bring real stability to the entire globe, perhaps for several centuries. At the same time, and maybe more importantly, a world at peace should allow us, the United States, to raise our standard of living significantly—a factor of two, three, four, ten, who knows what it might happen to be. However, to engender this kind of stability and a multiplication of living standards, we're going to have to craft a radically new military. To do so, we need to understand that the world in front of us is very, very different than the world behind us. In this world, only new approaches to national security and wealth building have a real chance of leading to the kind of exciting ends we can envision.

What is this world? You've heard parts of it today. Peter just talked about parts of it. Let me throw in a couple of other ideas.

We're currently experiencing, on an unprecedented global basis, three simultaneous revolutions, any one of which would be more than enough to shock and confound us. The first revolution, a geopolitical revolution, sees a single dominant power in the world for the first time since the fall of Rome. The opportunities that are inherent in this situation are extraordinary, as are the pitfalls. Unfortunately, there is no one around that has first hand experience in how to deal with this kind of a single power dominant world.

The second revolution, and there's been a lot of discussion about this so far, is the information revolution. As other people have mentioned, it is following inexorably in tandem behind Moore's law of computing power. Attendant to it, though, is not the creation of new ideas and technologies, but also an exponential growth in the velocity of information dissemination, and for us, that is of extraordinary importance. A key part of this information revolution has an awesome impact on competition. The business that introduced a new product ten years ago could count on probably five years before it had to look seriously at potential competitors based overseas. Today, you're lucky if you can count on five months or even five weeks before you are facing the overseas competitor. In today's world, success simply demands rapid introduction of successively new products or military systems. Success now goes to the organization which exploits information almost instantly, while failure is the near certain fate of the organization which tries to husband or hide ideas. Real simple—use it or you're going to lose it.

The third revolution, which is a little bit more complex, is the military/technological revolution, or in some places called the revolution in military affairs. I'm convinced that this is the first military technological revolution ever because we now have, for the first time, a

conceptually different way to wage war. We can wage war in parallel now. In the past, communications and weapons technology, especially weapons accuracy, have constrained us to waging serial war. This changes almost everything.

Understanding war in this military/technological revolution can be real difficult because it differs so much from our experience, but it's helpful to think about it, about revolutionary war, as being to old war much as quantum physics is to Newtonian physics.

Example. We're now seeing the eclipse of heavy armor, which in many ways epitomizes Newtonian or Clausewitzian war, war where mass was created by numbers and physical weight. It's interesting that this is the second eclipse of heavy armor. The first took place, as you all know, after Crecy and Agincourt where unkempt peasants with two cent bow and arrows were able to destroy knights wearing armor and riding horses that were worth hundreds of thousands of dollars in today's currency.

In the Gulf War we saw $8,000 precision bombs destroy $1.5 million, T-72 tanks with great ease. The heavy soldier is simply too easy a target to kill with weapons costing a fraction of his worth. The world is moving very rapidly from a historical era of mass flowing from numbers to a new era where mass flows from precision. Today, for example, one or two F-117s could put the ball bearing plant at Schweinfurt out of commission for far longer than could the hundreds and hundreds of B-17s employed against it in World War II.

One of the key effects of the military/technological revolution in a parallel war is the apparent domination of the offense. In the Gulf War, for example, Iraq lost quickly not because of ineptitude on her part, but because of what happened to her during the incredible time compression of devastating attacks. We hit three times as many targets in Iraq in the first 24 hours of the war as we hit in Germany in the entire first year of the American strategic bombing campaign against Germany. This is a time compression of three orders of magnitude. Very simply, nothing like this has ever happened to a country. Had we been the defenders with our equipment, and had we been attacked as we attacked the Iraqis, we would have lost as decisively as the Iraqis did. There is no defense today against parallel attack executed with reasonably, technologically fresh systems.

A little broader. War is likely to be a much different thing in the future, especially for the United States. The world, almost certainly, learned a lesson from Iraq's disastrous encounter with the United States. What did they learn? It goes something like this.

Whatever you do, don't put a big, expensive army in the field. Instead, try to bring strategic pressure on your enemies with ambiguous threats or actions which complicate the U.S. decision to intervene. If you do decide to take on the U.S., you simply cannot hope to beat her in the field militarily. Instead, you must figure out a way to attack one of her centers of gravity; perhaps an indirect attack on the people or an attack that causes lots of financial loss. In short, the Newtonian/Clausewitzian concept of the battlefield, the term battlefield itself, has either become or is rapidly on its way to becoming an anachronism.

The U.S., then, must find ways to attack the enemy's core systems in order to produce very rapid, direct strategic effects. These attacks will aim for near total avoidance of civilian and military casualties, and even much in the way of unintended property damage. There will be little likelihood of finding an enemy deployed in large numbers outside its borders and little

necessity to engage that force directly in any event. To carry out direct strategic attack with impunity, the U.S. will need a panoply of weapons guaranteed to thwart any defense.

We're in the midst of this information revolution in a world dominated by the superiority of the offense. We can project this revolutionary period well into the next century. In this world, relying on a policy of reacting only to an identified threat as the basis for our force structure, may be disastrous. We no longer have the luxury of depending on a rather sluggish Soviet Union to give us 15 to 20 years of response time. Instead, we have to consider any of a variety of almost 200 nations and perhaps an equal number of powerful non-state groups, or perhaps even other kinds of groups as Peter just mentioned. How could we conceivably be ready either offensively or defensively if we rely on reaction in this kind of an environment? This, to me, suggests the U.S. must abandon its old threat driven, force structuring system.

The U.S. is dominant militarily in the world today. The primary reason for this is its precision weapons with the ability to find targets for them, and the wherewithal to deliver them cheaply and rapidly. Without these attributes, the U.S. has no decisive advantage over most opponents. Although we need to improve precision in a variety of ways including all weather and precision of effect, the improvements we make are likely to be somewhat modest as opposed to the four order of magnitude change since World War II B-17s.

In the area of weapons delivery, we are likewise far ahead of the rest of the world, largely because of our stealth or stealth-like capabilities. Clearly, though, we cannot assume continued ability to penetrate defenses with impunity. Barring substantial improvements of our delivery capability, we will soon find ourselves unable to use our own precision weapons effectively and cheaply as will be required. Should this happen, we will lose our offensive superiority and be unable to further our interests proactively. What then?

The answer is simple. There should not be a "what then." Our objective should be to expand the lead we have over the rest of the world throughout the next century. By doing so, we will do more for world peace than any nation has ever been able to do. We must develop and field new systems rapidly to force potential enemies to devote impossible efforts to defense, or simply abandon military provocation. In other words, we become the threat. Instead of following our old practice of developing a new offense or defense in response to someone else's developments, a concept institutionalized in the acquisition milestone process and elsewhere within the government, **we** become the threat and force everyone else to react to **us**.

We should define and create the future we want, not wait to become the victim of someone else's future. The question then is not how technology will shape the Air Force, but how the Air Force will use technology to create the future that we have chosen.

Your first thought may well be that this is an impossible strategy in a low budget world. But is it? It is impossibly expensive only if we are stuck with Cold War ideas on quantities. Example. We have just over 60 F-117s, but the world must react to those F-117s just as if we had many hundreds. In the new age, mass comes from precision, not numbers. It is mass that does the job. Our problem, though, is the F-117s operate in a fairly constrained, well known altitude and speed block—clearly only a matter of time until someone learns how to deal with this regime. Our answer must be an F- 118 and an F- 119. Maybe a little more stealthy, but more importantly, something that operates in a significantly different speed and altitude regime; in a regime where the defenses developed against today's F-117s are unlikely to be effective. How

many F-118s, F-119s, F-120s do we need? Not many; probably just a squadron or two. The world must react more to a couple of these squadrons than it reacted to thousands of F-4s or F-16s which depended on numbers for their success.

How many different types should we have in the inventory? A lot, and all radically different. Maybe ten to fifteen substantially different air, space, information, kinds of platforms, each occupying a unique niche. Imagine trying to defend against this kind of a force.

We can call our new strategy a technological offensive. We should plan to develop and field a squadron or so of a new weapon system every three to four years. Small numbers are relatively cheap, if we start out from the very beginning with the idea of producing only small numbers and then throwing away the jigs, or converting them to something else. Think about how cheap was the very quickly produced, low number F-117 program. Fast means huge savings in program costs. Small quantities mean we don't need the huge infrastructure requisite for long production runs that almost always also demand the potential for unrealistic surge rates. Small and fast means lower program costs, which in turn means less congressional concern with excesses in profiteering. And finally, a new system every three years or so means that lots of companies will have frequent opportunity to win an F-117 sized contract.

Our technological offensive strategy would allow us to exploit the technology and the integration with which we excel. It means that potential enemies will be faced with multi-faceted problems which make defense next to impossible. It means we will always have a system in operation which is near state of the art—not exactly the case with the 20 year programs of today. Finally, we can have an affordable program even in an era when defense budgets may revert to their historical levels in the U.S. of 1.5 percent to 2 percent of GDP. Very simply, high-tech done right is cheap; far cheaper than the low tech attrition war equipment which is now such a large part of our inventory.

We can, in fact, have a very large standing Air Force even today if we measure size in output terms, effect on the enemy, rather than measuring size on inputs like the number of aircraft, tons of bombs, and number of sorties.

I would hope that we won't have to go to war again any time soon. If we do, however, I want to win; fast and cheap. I want to fight on our terms. I want to be able to dictate the outcome of the war at least as clearly as we dictated the outcome of the war to the Iraqis. I don't want a fair fight. I want to overcome the enemy in minutes—literally in minutes—without spilling a drop of unintended blood on either side. We can only do this, we can ensure a *Pax Americana,* if we press our technology advantages aggressively. Our goal must be to dominate the military technological revolution for the next century. We can do it if we adopt a new strategy consonant with the information revolution, not one mired in the first industrial age.

The Future of Government Funded Research

Dr. Robert M. White

Ladies and gentlemen, I'm not going to attempt to peer into the future. I spent most of my career peering into the future. In fact, fifty years ago I was a weather officer in the U.S. Army Air Corps, forecasting for B-29 flights over Tokyo, but I would like to place what the Air Force has to do in the future in a very much broader economic and political context.

I'd really like to address myself to the kinds of issues that we're now facing and are likely to face in the years ahead. If history is any guide, and we hope it will be given the events of two nights ago with the national election, there is a bipartisan interest in a strong national technology enterprise. The underlying reason is obvious. Every President seeks the advancement of the general economic performance of the United States as a fundamental goal. Presidents have differed, however, on how to harness science and technology as a means of achieving it. For many years, the debate has swirled around the question of whether intervention by the government through direct subsidies for research and development, or establishing incentives for private investment through economic, trade, education, and other contextual policies is the most effective way to gain the economic and social benefits.

There is, of course, general agreement that government funding of research and development to support government missions such as defense in space, as well as funding basic science, are proper domains for government direct investment. Although political ideologies change with changing Presidential administration, our national approach to harnessing science and technology has been pragmatic experimentation with many different modes. Administrations, both Democratic and Republican, have opted, when pressed for national security, economic or political reasons, to advance government intervention through direct research and development support as a means of fostering the general performance of the economy or large sections of it. The national track record, as we all know, has been dotted with both successes and failures. The Morrell Act and subsequent legislation going all the way back to 1862 set in place a productive agricultural system, the best in the world, largely through the commercialization of government supported research and development directed to this end. Today, primary food production in the United States occupies less than three percent of the working population. A century ago, some 40 percent.

Closer to the interests of the Air Force, of course, has been the National Advisory Committee on Aeronautics, NACA, established in 1915. Similarly, it conducted research and development that was a major factor in the achievement of the preeminence of the U.S. aviation industry. But failures have been similarly noteworthy. Synthetic Fuels Corporation, the supersonic transport, the Clinch River breeder nuclear reactor are all abortive attempts, through direct government support for research and development, to achieve some kind of leadership in those fields.

Finally, defense policy, very broadly, has had a remarkable positive feedback on the general economic performance of the United States. Our determination to achieve and maintain the technological superiority of the armed forces has had a strong impact on the performance of the U.S. economy. Many of our most advanced and profitable industries depended in critical ways on the spin-off from government supported R&D programs conducted in support of federal

government missions such as national security. The competitiveness of the U.S. aircraft, computer, communications, and materials industries owe much of their present superiority to the dual use nature of DoD investment in these fields. The spin-offs from defense and space research and development have also provided the human and physical infrastructures enabling these industries to take off.

This is not a new phenomenon. As long ago as the Civil War, the military need for mass produced weapons led the way to the machine tool industry and the concept of interchangeable parts. This, in turn, provided the foundation for mass production manufacturing systems that for many years, through the end of World War II, made U.S. manufacturing industries preeminent in the world.

A major change took place in the dynamics of technological advance after World War II. Technology became intensely science based. Chemical, electronics, aircraft, pharmaceutical, and semiconductor industries, largely through science based technologies, advanced rapidly from the flood of private R&D investment subsequent to World War II. So innovative and effective has this private investment been, that it is now widely recognized that "spin-on," the technology transfer from the commercial sector, is now necessary to maintain the technological superiority of the military.

Since taking office, this President's administration has embarked on a diverse and expanded effort to foster the general economic performance of the country by direct subsidy of R&D in areas of industrial importance while also moving ahead to establish economic tax, trade, intellectual property, and education policies to provide incentives for private investment in research and development, and the plant and equipment that embodies technological advance.

The new and expanded programs have been conceived as a response to a wide range of technological, economic, and trade pressures of a rapidly changing set of global relationships. For one, in a globally integrated, technologically interdependent economy, the success of modern industrial companies, and to a certain extent national wealth creation, depends upon the ability of corporations to serve the world market. The race for world market share has led to technology, trade, and economic policies in countries such as Japan and other nations designed to capture a large share of the world market even at the expense of beggaring their neighbors. A concomitant of the need for access to the global markets has led to a shift off-shore of production facilities in some industries, as well as the associated engineering capacity, with the attendant loss of employment.

Secondly, the nature of international industrial competition has changed. Joint government industry efforts abroad have targeted industrially important technologies, and have eaten away at the preeminence of some key U.S. industries. Wide bodied passenger aircraft produced through the combined efforts of the European governments and Airbus industries now command some 30 percent of the world market share. And as we know, flat panel displays are now essentially a Japanese monopoly.

In addition, the end of the Cold War left us a research and development enterprise that many feel exceeds the needs of the country. We are puzzled, for example, about what to do with the large federal government laboratory system designed to meet a different set of national needs. Reviews of the laboratory system are underway in the Department of Energy and the Department of Defense. The need to be globally competitive, coupled with compressed product

development cycles has forced a shift in private research and development investment to shorter term horizons. Many of the large private corporations have curtailed their investment in basic science and directed their efforts to more applied activities.

Finally, the burgeoning domestic budget deficit has forced federal spending limitations. Downsizing of defense activities and the changing time horizons of industry are, in addition, causing significant financial stress in our research universities, our federal laboratories, and in our R&D activities in industry. The stresses on the academic R&D enterprise are of special concern because of the dependence on it for the cutting edge knowledge that in the long term is necessary to remain technologically competitive, and upon which we depend for the training and education of the talent essential to the management and conduct of our technological operations, both in industry and government. The budgetary pressures are clearly revealed in this year's DoD Appropriations Bill with a significant congressional cut of $200 million from the $1.8 billion normally invested by DoD in basic and applied research in the university community. These pressures and others have resulted in an outpouring of ideas from the Clinton and previous administrations and many other institutions such as the Academies of Sciences and Engineering, the university community, and industrial associations on ways to address and adjust to these pressures. Measured against some of the main ideas, we can ask what kind of progress we are making?

Among these ideas is that the nation needs a meaningful technology goal for a new era. The Academies of Sciences and Engineering have proposed such a goal. It should be to ensure that the U.S. maintains a position of leadership in those technologies that promise to have major and continuing impact on broad areas of industrial and economic performance. To achieve this goal, government must master a new role—the support of industrially important technologies where the government is not the principal customer. It must do this without government direction of industrial performance or interference with market forces that drive economic events. In short, the government must do this in partnership with industry. Building on the initiatives of both the Bush and the Reagan administrations, this administration has embarked on an intensification of such efforts as the advanced technology program in IST, the cooperative research and development agreements, both cooperative government/university efforts involving direct research and development support for promising technologies of industrial importance. At the urging of Congress, DoD subsidized the privately administered industrial consortium which we all know as Semitech, to restore the international competitiveness of the U.S. semiconductor industry. The administration has launched new industrially relevant R&D initiatives, including the dual use technology program of DoD (we call it the technology reinvestment program).

As importantly, to achieve this goal, it has proposed a shift of government R&D investment from the support of military to civilian R&D. The administration appears to be making good progress in this reallocation of R&D funds toward a goal of an even split between investment in military and civilian R&D. Proposals from many organizations and the central feature of the Clinton technology policy have urged government efforts to foster the adoption of new technology in small and medium sized manufacturing firms. The government has now funded and begun to implement the network of such manufacturing and technology extension centers. Almost all proposals for more effective harnessing of science and technology for economic growth have advocated strong efforts by government to shape contextual policies to create incentives for private investment. The lowering of trade barriers, the reduction of the deficit—on these fronts,

I think the administration has moved forcefully. The successful conclusion of the GATT negotiations and the adoption of the North American Free Trade Agreement (NAFTA) have been major market opening and trade liberalization achievements. The persistent market opening negotiations with Japan, although slow, are moving in the right direction. The reduction of the budget deficit from close to $300 billion to a projected $170 billion in 1995, is really a triumph.

What does all this mean for the Scientific Advisory Board of the Air Force and the Air Force itself? Simply, that to an unprecedented degree, the technological superiority of the Air Force cannot be divorced from the technological advancement and the general performance of the economy. It means that the Air Force has a fundamental and critical stake in the broader economic, education, and technology policies of the federal government and its horizons and those of the SAB need to encompass this broad range of technological and economic issues in the future.

The Future from An Industry Vista

Dr. Robert J. Hermann

I am from industry, but those of you who know industry know that it's not a sector that you can represent. It is, at least, some experience in industry. My role in my corporation demands that I have some view of the future and so I have developed a set of reasonings and arguments, and what I'm going to do this afternoon is try to express those and provide a framework for what industry and the industrial process is going to look like in the future. I'm forcefully doing it in the same sort of way I would as if I were trying to project the basis for planning for a corporation who has to try to imagine living through the next ten or twenty or thirty years. So the information revolution in my mind is the keystone of predicting how enterprises, how societies are going to behave in the future.

This has led, in particular, to globalization. It has also been mentioned, but I have to do it in my own particular way. It means that anyone who is in business, in almost any business in any way in any part of the world, has to imagine that it's dealing for markets (that is, people to buy things), anywhere in the world. That industrial processes and production processes will be used from all parts of the world. All parts of the world will be candidates for sources of industrial processes. All parts of the world will be candidates for access to technology.

The enterprise, the corporation, will reach to all parts of the world. The sovereignty issue has already been raised by Dr. Bishop. Corporations such as mine, and many other well known American names, are now more than fifty percent revenue-driven from outside the United States. More profits are derived from revenues outside the United States and there are more people living and working outside of the United States in many cases carrying different than United States passports. So the nature of a multi-product business is now tending very much to be international, multi-national, or multi-domestic in nature.

It causes interdependence, and of course interdependence always existed within the industrial sector, and now that interdependence is naturally spread across international lines in a way that is unprecedented with the past and will become more smoothly interdependent in the future. That will come back to be an opportunity or a problem for the Air Force and for the military in other ways, it may be an opportunity.

Also occurring, largely driven by the information revolution, is the integration of industrial functions. At the easy-to-describe level, integrated product development and integrated product teams, concurrent engineering, synchronous engineering, are putting together engineering and manufacturing in modern corporations. In many corporations, in the most modern fields, they already don't have engineering departments. In the future, most will not. But it's not only in engineering and manufacturing, it's also carrying the product into the field. The integration of skills and responsibilities and authorities are crossing the design of a product to the design of a process to use the product in a way which is integrating the functions in enterprises which create products of value.

In its own way, this is requiring a broadening of the skill base and capability of the technical professional. There aren't as many stovepipes in modern industry today, and they are quickly vanishing. A technical professional has to have command of materials, information systems, to

be an aerodynamicist as an example. You can fill in many of the blanks. But what it does mean is that there is a cross-discipline requirement to be of value to the money-making enterprise in the future.

Furthermore, the burden of understanding the business context of a technical professional is requiring that the technical professional understand more about business, finance, society, law, and thus there is need for a renaissance style behavior in the technical professional that I believe has not existed as much during most of my adult life. There is another integration of function which I've labeled "white collar/blue collar." In the restructuring and re-engineering of manufacturing activities, great stress is put on teamwork, moving away from supervision, and causing the maximum use of each individual according to the mission (or function) of the small enterprise that constitutes the making of the part or the creation of this service. In many cases, this is moving what we used to call an engineering activity, to the responsibility of someone who is not professionally educated as an engineer and would be called "hourly," "blue collar," or whatever pejorative term we might use. In addition to a spreading of competence requirements across the technical professional, we are spreading engineering functions down to the lowest level in order to maximize the value of each individual in the enterprise. Teamwork—teams as a style of operation—and flattening of the organization have changed how the burden that each must share in the context of the enterprise being a success. As you look forward to either using industry or modeling organizations in response to how industry is doing it, these manifestations will show up.

I want to give a commercial now for acquisition reform. Many of you know that I am involved in this process, but since I'm involved in it, I have deep conviction, so I will spend a minute or two on it.

Let me describe in the harshest of terms what I believe the problem is. We have become accustomed to basing our security and our weapons and our capabilities from being drawn from a dedicated, isolated, and separate defense industrial base. That separate defense industrial base, over the course of time, has undergone, and is undergoing, and will undergo more, a tightening, a reduction, and it will attract less capital and fewer of the best and brightest. It will not be the basis for the highest technology in the most advanced fields. It will not be the source of the most efficient industrial processes. Its isolation and its peculiarity is based on a set of byzantine, bizarre, and unreasonable compliance practices visited upon the suppliers to the Department of Defense.

We run the risk, therefore, of basing our security on not only a sector which is going to be higher cost, but will reward us with less modern technology and less modern industrial processes. These latter two are even more important than the horrendous cost that we pay for the burden of this system.

The solution, I believe, is that we must move to commercial specification, as Dr. Perry has already moved to do; commercial standards and commercial practices, which he has a start on. One of the most important elements of commercial practice is that in commercial practice the buyer has an idea of the value of the thing to be bought and thus has an opportunity to judge the price and base it on the value itself. Our current process is not that. It says that we have a requirement, and now the issue is to discover how much it will cost us. Therefore, no matter what the form of contracting is, with few exceptions in the buying of straight "commercial

products," we have cost-based contracting which in a sense says, "I don't know what to pay for what you're going to give me so I'm going to spend a great deal of time, attention, and your money and mine, examining how much it costs so that I can pay you just a little bit more than that." When I explained that to my barber in Des Moines, he said, "You're kidding me. That's not the way we do that, is it?" Sure enough, it is.

So one of the great new things that has to come about is, we have to spend some time worrying about the value of what we're going to incur. Value, of course, it's difficult to define, but the way I believe that's done in commercial practice is by examining alternative options: alternative courses of action as options.

I use the 747 as an example. If you want to have a 747, you're going to have to buy it from Boeing. On the other hand, you can have an airline without buying a 747. Therefore, you have a bargaining position with Boeing. You can establish the price that you will pay by examining the cost or the price associated with alternative courses of action, not all of which are a competitive bid against a common specification. I think it will be very important for us to be able to draw on the commercial sector and we will not be able to do that unless we move to commercial practice.

There's another important process surrounding the industrial base, but it becomes political. It has a lot to do with what John Warden talked about, and that is the fractionization of the geopolitical or the world political structure and the emergence of the United States as the only super power. This is of interest to a business who must be global in nature, and with employees particularly who had been accustomed to operating out of the U.S. safe haven. We have to decide what role the United States is going to play and how it's going to play that role. I'm mindful of the admonition that the United States cannot be the policeman of the world. On the other hand, I would like it if the world were more or less orderly and therefore, as the super power, I believe my country has some obligation to help arrange for an orderly world within which commerce and the "pursuit of happiness" can be waged. Since we occupy a position on the stage that no one else does, we have a special responsibility. That responsibility is heightened by noting that we are a nation of 250 million people in a world of about 5.2 billion. I think we're a little less than five percent. So certainly one man/one vote is not going to be exactly the first thing we're going to argue for. We're going to have to find a way to achieve the well being of our citizens with some other mechanism.

At the present time, I believe that about eighty percent of the economic activity of the world is enjoyed and undertaken by less than twenty percent of its citizens, and twenty percent is undertaken by something more than eighty percent of its citizens. Since we have information proliferation, a lot of those other four billion have noticed that, and it annoys them. They are, in fact, working hard to make economic progress. China has 1.2 billion people and I've been there and see the progress and it is phenomenal. The Indian subcontinent has another billion or so. That fourty percent slice of humanity is moving to become equivalent. We already know that with the proliferation of information the human being has the capacity to learn, and the lifetime of learning is not too much longer here than there. So we have to measure ourselves in this future world differently than we have in our past.

We have a comparative advantage that is based not only on our superior military forces, which I believe we should retain; not only on our superior and larger economic base, which I believe we should retain; but that one of the bases for retaining that position is our ability to

integrate. Our ability to integrate is, in some sense, based on the diversity of our culture. We have the diversity and individual nature of our culture, our history, and our ability to do systems thinking and systems organizing. I believe this is a discriminant advantage for this country and one which we should maximize, and one which is not as amenable to transfer to other societies as readily as some other leverages for economic wealth.

I believe that means that we must choose the top five percent. As five percent, we are going to be in a sense, inequitably better treated than the rest of the world. We will have to add inequitably more value. To do that will be the integration, the management, and the leadership function appropriate to the economic military and ideologic leader in the world. That means that we will have to share the responsibilities for security, so coalition security is what I would imagine must evolve as the basis for a world order which will permit commerce/industry to flourish. It is consistent with every other element of strategy that we have coalition interests with our national neighbors. We have coalition security requirements, and we have coalition economic interests.

I would like to say a word about the outlook for defense in this environment. It seems that painting that scenario where the primary basis of the welfare of our country is measured in economic terms in our citizenry, that we are going to have to maintain a superior military capability, but we'll have to get better at describing how much capability is required to achieve which objectives and how those fit. It is my impression at the moment that we have not done as good a job as we need to for our citizenry, and when I was last talking to my barber in Des Moines, he didn't quite understand why we needed as much as we did compared to the rest of the nations. I think that case has to be made better. The form of these forces I will just say that John Warden has described many things which I would subscribe to as the tonal quality or the flavor of what forces are likely to be both needed and affordable in the future.

As for the role of the Scientific Advisory Board, it seems to me that the notion of having an SAB which connects the military thinking process and the military force building process with the technical community, the university community, and the industrial community is an absolute essential. Those communities are changing very rapidly at this point in time, and a continued process for intimate interaction between those sectors is essential for the Air Force, it is essential for the Department of Defense, and it is essential for the nation. I hope the next fifty years are as successful as the last.

Concluding Remarks

Dr. Gene H. McCall

That concludes our program for today. I did have a couple of points I wanted to make here, lest we be too impressed with our own infallibility, as we embark upon a long range forecasting study which could be important to the future of the Air Force. I prepared just a few slides of famous predictions that I thought you might be interested in.

"Heavier-than-air flying machines are impossible."
One from Lord Kelvin, one of the most famous physicists of the 19th century.

"Man will not fly for fifty years."
Wilbur Wright's statement two years before he actually did fly.

"The radio craze...will die out in time."
Thomas Edison's comment about radio. These things have kind of a twisted way of coming true. The radio craze did sort of die out.

"I think there is a world market for about five computers."
That statement by Thomas Watson, IBM's Chairman of the Board in 1943, that could be IBM's share in a few years. (Laughter)

"There is no reason for any individual to have a computer in their home."
That statement by Ken Olsen, President of Digital Equipment Corporation in 1977 seems true—hardly anyone has a Digital Equipment computer in their home. (Laughter)
I didn't leave the military unscathed.

"I will ignore all ideas for new works and engines of war, the invention of which has reached its limits, and whose improvement I see no further hope."
Vespasian's Chief Military Engineer, Julius Frontinius, said this in the First Century AD.

"The bow is a simple weapon. Firearms are very complicated things which get out of order in many ways."
That's certainly true. Colonel Sir John Smyth made a very eloquent argument for staying with the bow rather than switching to muskets.

"[The machine gun] is a grossly over-rated weapon."
That statement was made by British Field Marshal Douglas Hague about a month before the start of World War I.

Fifty Years From Now... Forcasting the Future

Introduction

Today, it is no longer possible to gather the majority of America's aeronautical scientists in one university auditorium. The surreal explosion of computer technology and the expansion of aeronautics into astronautics, and all of the disciplines which are related to advances in these areas, makes comprehensive individual reports a true impossibility. No longer can one scientist know all there is to know in one field of study.

But many scientists will tell you that, every once in a while, an individual brilliant thought triggers a breakthrough. This is the purpose behind these essays. Perhaps in reading these individual thoughts about the future, a moment of brilliance will result within you and trigger a breakthrough in your field. It may not happen this year or in ten years, but it might happen someday. Fifty years ago, this kind of individual thought resulted in the creation of *Toward New Horizons*, the blueprint upon which was built the supremacy of today's Air Force. The nature of forecasting in the Air Force has gone through many iterations. The first forecast was produced by only 31 of the nation's finest minds. The current forecast team is nearly five times that size. But times have changed.

In November 1994, Secretary of the Air Force, the Honorable Sheila Widnall, challenged the Air Force Scientific Advisory Board to "rekindle their inquisitive attitude" which had originated one half century before when Dr. Theodore von Kármán was tasked by General of the Army, Hap Arnold, to look to the future and make a report—a blueprint—on which to build an independent Air Force. As part of this current study, *New World Vistas*, Dr. Gene McCall, SAB Chairman, asked the members of the Board to take an individual shot at the future. What follows are the results of Dr. McCall's request.

FROM: Dr. Gene McCall, Director

SUBJECT: Panel member "long look" for Summer Study 95.

TO: All *New World Vistas* Panel and Working Group Members

1. Dr. Theodore von Kármán once said, "In the long run, I still think that the finest thoughts come not out of organized teams but out of the quiet of one's own world." In that spirit, and as part of the *New World Vistas* final product, I am requesting each of you, on a voluntary basis, to write an anonymous, 1000 word (or less) essay which looks 50 years out into the future. Try to disregard current technology and stretch your mind into the next level of possibilities. Don't be afraid to go "way out" in your forecast. For those of you involved in working groups and not on NWV Panels, this may be your only opportunity to contribute to the final product. I encourage you to do so, creatively.

2. I hope that these essays will add the element of "the quiet of one's own world," which Kármán referred to many years ago. By keeping them anonymous I hope to eliminate any hesitation to reach out for those ideas which today may be only within the mind of one individual. Be bold and imaginative.

3. These essays will be collected at Summer Study 95 and should be in the following format: 3.5" DS/HD disk, MS Word or WP 5.1, and not longer than 1000 words. Point of contact at the SAB is Major Dik Daso, at (703) 697-8404 or (703) 425-8985. (FAX available at that number).

4. Thanks in advance for your effort. I realize that many of you are already committed to other writing projects but this request requires no resource other than your imagination. Have fun with it.

Dr. Gene McCall, USAF/SB
Chairman, *New World Vistas*

Fifty Years Hence

The world will have changed dramatically. The world population will have expanded by a factor of 2 1/2 to almost 15 billion people. The Asian nations will have huge economies and the demand for resources will have made many scarce, particularly oil. The military mission will have shifted from primarily warfare to enforcement of sanctions and relief type missions. Where direct intervention is called for the need will be for precision strike of military targets with minimum to no collateral damage to civilian populations. The main trouble spots will be in the developing nations as the developed economies will be too intertwined to risk wars.

Space will have become a major factor in world power. Aircraft will only carry enough fuel for take off and landing plus a margin for emergency. Their main power source will be laser beams from satellites locked on the aircraft by beacons to transmit power in the form of heat that will be used to expand and accelerate the air through the propulsion system. This will be necessary because of the scarcity of petroleum type fuels. The Air Forces Mobility Command mission will be greatly expanded and with fleets of large laser powered aircraft Global Reach– and Global Power will truly be realized.

Space will be the key to maintaining air supremacy in that the Airborne Warning and Control System (AWACS) type missions will be carried out from space. While the actual controllers may be on the ground the entire battle area will be presented in virtual reality. The constellations of satellites will include multi-frequency radar and hyper-spectral scanning optical systems that will defeat most forms of stealth. Large high powered laser platforms will allow the controllers to destroy any aircraft in a given keep out zone. The same high powered laser systems will be an integral part of the National Missile Defense (NMD) system for protecting the nation and the world from terrorist ballistic missile attacks.

Close air support with manned aircraft will become a thing of the past because of the large number of sophisticated air defense weapons that will be available to rogue nations. Rather, the approach will be to use Uninhabited Aerial Vehicles (UAVs) that are flown by pilots out of harms way in ground shelters interconnected to the UAVs through satellite links or high flying UAVs that provide communication connectivity. UAVs will also be the primary method of providing full time battlefield surveillance augmenting satellite resources that will be primarily in the search and detection mode of operation.

Strategic strike with long range bombers will have largely been displaced by the introduction of transatmospheric vehicles that are combined hypersonic aircraft and rocket ships that take off and land horizontally and can achieve sub orbital flight. They will make it possible to strike anywhere on the globe in less than two hours. While they will be expensive to procure and operate they will be of immense value in the Global power equation.

Among the capabilities needed will be man in space to support the development of large solar collectors as well as maintaining and updating the large radar and laser beam systems. Similar to aircraft systems, large space platforms will have lifetimes of thirty years or more and the subsystems will be updated and replaced to keep the platforms up to date relative to the evolving threat and technology. Space lift capability will evolve to Single Stage to Orbit (SSTO) spacelifters and because of their reusability will greatly reduce the cost of access to space.

The Air Force role will be increasingly important as we as a nation shift from a superpower based on nuclear capability to a super power based on space domination. The true meaning of Global Reach and Global Power will only be realized through superior space capability which is dependent upon developing the supporting technologies.

Management of Technical Risk

While the section of the report on the relationship of technology transition to the acquisition process dealt with and was oriented to technical risk, this section will address the environment for technological risk taking, and some methodologies for helping to reduce technological risk.

First, we must recognize technological risk will be inherent in most future programs. This is not immediately apparent because upgrades and modifications are normally thought of as low risk programs. In the future, however, we will stay much longer with existing platforms while applying significant changes to their electronic, propulsive, and weapon devices.

To maintain technological superiority we must ensure these significant technological changes, therefore successful risk management becomes a requirement, not a nicety.

The current risk avoidance bureaucratic OSD review process encourages obfuscation of risk. Therefore, the leadership must first exhibit a constant behavior concerning the following:

- Making risk visible
- "Attaboys" for good risk matrix work and for good retirement strategies
- Publicize constructive failure (i.e., we proved early it wouldn't work and saved MEGA dollars as a result)

Second, in order to short circuit the "no-ability" of the staff, a single designated per program technically competent risk analyst shall be appointed to conduct the visa review for the ASA R&A...he shall be encouraged to work with the Program Manager (PM) as the PM develops the risk matrix, and to guide and question the PM during the risk matrix review. No other member of the staff shall be allowed to create work for the PM. The objective is not to entrap or create work for the PM, or to show how smart the review is ... rather the objective is to provide constructive guidance, help, and encouragement.

The most fundamental risk that officials must manage is the risk if system does not perform adequately in battle. If a device or machine does not work for its intended purpose, then the program is a failure. All the smart contract clauses and detailed testing are of no avail if we fail to ask the single all-encompassing question, "Does this thing do its job?"

The recommended two-step acquisition strategy focuses on this jugular issue. It is appropriate, then, to address some details of risk reduction, and make further recommendations for their implementation.

Tools to Manage Risk

The following management tool development is recommended.

- An Air Force/Industry PM team should develop a one-page risk identification format which will be filled out within three months of program start. This risk format will be used by the PM to track his status against performance specifications until the end of phase one, when it is available for Under Secretary of Defense (Acquisition & Technology) USD(A&T) review.
- A risk sieve or Red Flag list should be developed. Experience has shown many technology risk areas are common across many programs. This Red Flag list will help the PM attack most (but there is no promise of all) technological risk areas.

It is important that a team of Air Force/Industry PMs develop this list in order to capture the experience which exists. The four area groupings and examples are a product of our experience and intended for illustrative purposes, and as a basis for an action item:

Group	I	Electronic Risk
Group	II	Software Risk
Group	III	Electromechanical Risk
Group	IV	Materials Risk

As an example, electronics risk might include:

1. Any new or modified high power RF tube or transistor.
2. Any new process large scale integration (LSI) chip.
3. Any LSI chip with less than 2 micron feature size.
4. Any frequency synthesizer.
5. Any power supply employing chopper technology.
6. Any focal plane array.
7. Any charge coupled device (CCD) or infrared (IR) sensor.

Software risk might include:

1. Real-time system.
2. Real-time distributed system.
3. Real-time imbedded microprocessor system.
4. Unique data bases.
5. Distributed data bases.
6. Relational data bases in real-time systems.

7. Dynamic resource allocation/on-line load leveling.
8. High number of source lines of code:
   a. Greater than 1,000,000
   b. More than twice as many as in prior experience.
9. New hardware architecture or new software language.
10. Unfamiliar security requirement.
11. High PMFL requirements.
12. Lack of unavailable alternative approaches.
13. Inappropriate requirements too restrictive for required functionality.

The application of these types of lists to any particular program would follow this thought process:

1. Do I have such a risk?
2. If yes, is it a high risk?
3. If high risk, do I have a backup approach? When must I prove it to have a chance of recovery?
4. If low risk, nevertheless, I must schedule proof of performance before R&D is over. When does it best fit within the normal sequence of development?

This would be done for every Red Flag item even if the designer insists there is no risk (if such is the case, he'll have no trouble meeting the specs and schedule).

Cynics may speculate if PMs will obfuscate or hide big issues. However, if we insist on a review of an original one page risk matrix and answers to the questions, "Does this thing meet its operational objectives? Does it work?", the probability of avoiding Engineering and Manufacturing Development (EMD) with unproven technology is significantly enhanced.

Some probable questions about this approach:

- Does this mean we will build more prototypes than in the past? Probably.
- Does this mean we may need to use two or three technology alternatives to ensure risk reduction? Yes, sometimes.
- Are you telling me that all software operating systems must exist and be proven under load by the end of Research & Development (R&D)? Yes.
- Will you accept simulation of traffic flows (both intra and trans system) as demonstration of proof? No, we need actual hardware and software demonstrations.
- Will you accept Training & Doctrine Battle Lab simulation of operational performance to EMD? No, the Battle Labs are a necessity to establish operational need and provide a test bed for a program to interface. If there is technology risk associated with battlefield integration, you will prove it with actual prototypes.

There will be a thousand healthy questions spawned, the important thing is they will occur during R&D and not during EMD.

We recommend that we trust the Government Industry team to provide us a risk minimized system. The control on that trust is the single USD (A&T) review between phase one and phase two.

Last, we must recognize high turnover of personnel, and loss of "corporate" memory in both the Air Force and Industry. Some of this "lost" knowledge can be impacted by training. We recommend a Defense Systems Management College (DSMC) course in risk reduction specifically featuring the development of the red flag list, the summary risk matrix, and the use of DIS and the Battle Labs...for combined Air Force/Industry attendees.

Biological Process Control

Looking 50 years into the future is extremely easy and, at the same time, exceedingly difficult. Easy, since I will not be around to catch the flak for being very wrong. Difficult, since it is really presumptuous to pretend that you have the vision to see the future. Nonetheless, you asked for it and here goes.

As we look forward to the future, it seems likely that this nation will be involved in multiple conflicts where our military forces increasingly will be placed in situations where the application of the full force capabilities of our military might cannot be applied. We will be involved intimately with hostile populations in situations where the application of non-lethal force will be the tactical or political preference. It appears likely that there are a number of physical agents that might actively, but largely benignly, interact or interfere with biological processes in an adversary in a manner that will provide our armed forces the tools to control these adversaries without extensive loss of life or property. These physical agents could include acoustic fields, optical fields, electromagnetic fields, and combinations thereof. This paper will address only the prospect of physical regulation of biological processes using electromagnetic fields.

The literature regarding the interaction of biological processes with electromagnetic fields is growing at a rapid rate. Sources are becoming more available, biomedical instrumentation is improving so that the interactions between biological processes and physical fields can be examined with fewer artifacts, and the principles underlying these interactions are becoming clearer and more amenable to theoretical prediction.

Prior to the mid-21st century, there will be a virtual explosion of knowledge in the field of neuroscience. We will have achieved a clear understanding of how the human brain works, how it really controls the various functions of the body, and how it can be manipulated (both positively and negatively). One can envision the development of electromagnetic energy sources, the output of which can be pulsed, shaped, and focused, that can couple with the human body in a fashion that will allow one to prevent voluntary muscular movements, control emotions (and thus actions), produce sleep, transmit suggestions, interfere with both short-term and long-term memory, produce an experience set, and delete an experience set. This will open the door for the development of some novel capabilities that can be used in armed conflict, in terrorist/hostage situations, and in training. New weapons that offer the opportunity of control of an adversary without resorting to a lethal solution or to collateral casualties can be developed around this concept. This would offer significant improvements in the capabilities of our special operation forces. Initial experimentation should be focused on the interaction of electromagnetic energy and the neuromuscular junctions involved in voluntary muscle control. Theories need to be developed, modeled, and tested in experimental preparations. Early testing using in vitro cell cultures of neural networks could provide a focus for more definitive intact animal testing. If successful, one could envision a weapon that would render an opponent incapable of taking any meaningful action involving any higher motor skills, (e.g. using weapons, operating tracking systems). The prospect of a weapon to accomplish this when targeted against an individual target is reasonable; the prospect of a weapon effective against a massed force would seem to be more remote. Use of such a device in an enclosed area against multiple targets (hostage situation) may be more difficult than an individual target system, but probably feasible.

It would also appear possible to create high fidelity speech in the human body, raising the possibility of covert suggestion and psychological direction. When a high power microwave pulse in the gigahertz range strikes the human body, a very small temperature perturbation occurs. This is associated with a sudden expansion of the slightly heated tissue. This expansion is fast enough to produce an acoustic wave. If a pulse stream is used, it should be possible to create an internal acoustic field in the 5-15 kilohertz range, which is audible. Thus, it may be possible to "talk" to selected adversaries in a fashion that would be most disturbing to them.

In comparison to the discussion in the paragraphs above, the concept of imprinting an experience set is highly speculative, but nonetheless, highly exciting. Modern electromagnetic scattering theory raises the prospect that ultrashort pulse scattering through the human brain can result in reflected signals that can be used to construct a reliable estimate of the degree of central nervous system arousal. The concept behind this "remote EEG" is to scatter off of action potentials or ensembles of action potentials in major central nervous system tracts. Assuming we will understand how our skills are imprinted and recalled, it might be possible to take this concept one step further and duplicate the experience set in another individual. The prospect of providing a "been there-done that" knowledge base could provide a revolutionary change in our approach to specialized training. How this can be done or even if it can be done are significant unknowns. The impact of success would boggle the mind!

Toward a New Air Force Paradigm

All the technology in the world will do the USAF no good if it can not be obtained quickly, easily, and continually. Today's whirlwind of computer hardware and software improvements are increasingly transient. Exponential improvements and lower costs occur in weeks rather than years. Without a radical change in the USAF system of acquisition, outmoded systems will be purchased at substantially higher costs than more efficient systems which become available on a soon-to-be weekly basis.

The answer is for the Air Force to become a "consumer" of civilian technologies rather than a "developer" in their own right. Although it is true that certain unique characteristics concerning security and utilization of force are generally considered military domain, civil industry has already developed sophisticated programs to guard their own company's secrets locked within corporate computers. Certainly the Air Force might do the same by hiring civilian experts and firms as contractors for this purpose. The Air Force and Microsoft, as an example, should be doing business together well into the next century.

Without radically revamping of the "process" involved in acquisition, the Air Force will not be able to hold a qualitative edge in computer, and more importantly information technology through the next century. For example, the Air Force (all services for that matter) should have a contract with a few of the world leading computer companies which includes continuing updates to software *and hardware*. To continue purchasing systems because they are the lowest bid will inevitably deliver a substandard overall system, one incapable of meeting the future demands of the expanding computer literate world. Certainly, antiquated computer technology will be incapable of managing information systems which will dominate world systems in the future. The "enemies" of the future will have no such acquisition restrictions and will also hold the purse strings of a great deal of money (drug dealers, oil rich nations, or other splinter groups).

Part of the Air Force's future is increasing control of space. Information will be the key to the future of war, business, travel, communications, politics, everything. Mobility in the space environment will be essential for the maintenance of the "information network." Consequently, both manned and unmanned space systems will be needed. Unmanned systems will provide the hauling capability while manned systems will provide the ability to manipulate objects not under direct control of the appropriate world powers. The single stage launch vehicle under development by McDonnel-Douglas may provide the immediate answer to both of these missions. Inevitably, a space based presence will be continually required to meet repair and control missions. A space station is the next logical step in assuring that space control is achieved. The Air Force must take a more active role in establishing and expanding manned presence in space. The distant future will inevitably require space colonies, interplanetary travel, and eventually figuring out how to stop a star from turning into a red giant. There will always be room for theoretical physicists in the planetary system.

In the future, combat air forces will continually emphasize "minimal casualties" on all sides. To assure this is achieved, pilotless craft will become the weapons carriers in future conflict. Cargo and personnel (National Treasure) will always be carried by manned craft. **For the USAF, preservation of lives on our own side will be entrusted to airmen while preservation of lives on the enemy side will be entrusted to technology: its accuracy and**

capability. However, I do not believe that the concept of "non-lethal" weaponry will survive into the year 2025. Those who challenge authority will continue to behave much as cornered animals. Unfortunately, sticky foam or rubber stun bullets will not deter or convince those who challenge authority. They will not be convinced that submission is the only option. Deadly, rapid, decisive use of force will be the only way to ensure minimal excursions from the status quo which the US will continue to define for quite some time.

Peace time missions will continue to expand into the military services in the next century. Perhaps a "Peace-time Command" made up largely of commercial transport planes and goods and services contractors will develop into an National industry during the next century. This would likely be a lucrative venture for the commercial sector, would allow a smaller military, and therefore be a political "plus" in the days of shrinking government and budgets.

As to the "social" future of the USAF, I believe that societal trends will once again prohibit women from combat zones of any kind. This will occur not because women can not do the job but because mores in the US will shift so that a majority will once again favor protection of females rather than equality for equality's sake. There will be no tolerance for homosexuality or other "non-traditional" behavior among the ranks. There will be more tolerance for shifting views in personal appearance. There will be less tolerance for lackluster performance in the workplace. Housing and pay will improve while Air Force size will continue to shrink, even into the next century. The "Fighter Pilot" of the future will not sit in an F-22. He or she will sit in a virtual simulator, linked with other unmanned fighter planes somewhere far from the battle zone (hence women will be able to serve as future fighter pilots while cargo and transport pilots facing the actual bullets or directed energy "ray" guns will be men). The next major paradigm shift will require acceptance of the "computer wizard" as the combat warrior of the 21st Century.

The greatest single change in civil aviation will be the practical use of nuclear reactors in aircraft. Dependence on petroleum based fuels makes little sense into the next century. Nuclear energy, most likely a small fusion reactor, will allow the aviation industry to operate virtually fuel cost free. Transportation costs would stabilize and prices would drop so low that anyone would be able to afford them, that is, if money is still used. The logical follow on to practical nuclear power for aircraft will be space beamed power systems for commercial travel craft of all kinds.

Fifty Years into the Future

Two things are certain about the future: first, it is different from the present and the past, and second, whatever we predict today is bound to be wrong. Why predict at all, then? Because predictions, if logical and informed, comprise a set of possible futures. None of these may actually occur, but they provide a set of "what-if's," against which plans and strategies can be assessed. Thus speculation on the future can protect us from embarking on a course of action which could be disastrous if certain events, even if they are unlikely, come to pass.

The likelihood of surprise increases with the detail of the prediction and the technological content. Thus an informed prognosticator in 1895 would probably have predicted that the great European powers were on a collision course, and that the continent would be devastated by war during the next half century. He or she would likely have predicted that air power would play an increasing role in military operations during that time, but would have been very unlikely to predict the invention of nuclear weapons, since even the basic physics was then completely unknown.

It would have taken no great predictive skill in 1945 to foresee a half century of conflict between the Western allies and the communist world. The predicted consequences would have (and did) range from mutual nuclear annihilation to an armed stand-off. Possibly a bold and courageous prognosticator would even have predicted the actual outcome, the collapse from within of the Soviet empire. Again, it is unlikely that anyone could have predicted the greatest technological advance of the era, the development of semiconductor electronics. Even those who did anticipate that communications technology would revolutionize society, like George Orwell, completely missed anticipating the effect on society of that technological revolution. In writing *1984*, Orwell saw communications technology as a force enhancing the strength of totalitarian central government. In doing so, he got the sign wrong; the effect has been just the opposite.

These examples are adduced to make a point: we can probably predict the societal changes and challenges of the next half-century with some confidence, but it is more difficult to predict what technologies will emerge in the same period, and we can miss completely major societal impacts brought about by those technological changes. It is important, however, to note that generic technology changes can be predicted with some confidence, while specific technologies are unlikely to be known fifty years in advance. Based on the experience of the Franco-Prussian war and the US Civil War, in which civilian populations were placed in harm's way, along with the beginnings of chemical warfare, the thoughtful observer of 1895 probably would have anticipated the emphasis on advent of weapons of mass destruction, even though the particular technologies were unknown. Similarly, advances in precision weapons would have been anticipated in 1945, even without knowing exactly how that precision would be achieved.

What are the likely political trends of the first half of the 21st Century? The present trend toward fragmentation in societies that are emerging from imperial rule, like those in Africa, and Eastern Europe, will continue. Consequently, there will be a continuing level of insurrections, civil wars, and tribal warfare in those regions. The outflow of refugees will be primarily to Western Europe, and will become one of the major economic and social problems for countries like Germany, France, and Great Britain, causing deep divisions in their political structure.

Similarly, in the Western Hemisphere, the influx of refugees from the economic and political instability of Latin America will play a larger and larger role in US politics. The Western democracies will be forced to try to close their borders, for both political and public health reasons, but these actions may be strongly opposed by large segments of their populations.

The public health aspect is extremely disturbing. In sub-Saharan Africa today, large segments of the population are living with badly damaged immune systems. Not only AIDS, but parasitic infestations, tuberculosis, cholera, and other chronic infectious diseases flourish in these populations. Due to the civil unrest in the area, there are large populations of refugees with damaged immune defenses living in unsanitary conditions, sometimes in settlements of close to a million people. These provide a unique breeding ground for new forms of viral and bacterial diseases. Limiting the spread of these diseases will be one of the major concerns of society in the next fifty years.

The current situation in Africa will probably spread to other regions of high population growth and civil unrest, in Asia and South America. Rapid, non-invasive medical diagnostic technology will be developed and deployed at national boundaries, and international airports. The technologically advanced countries will set up enclaves in the third world, to which access will be rigorously controlled. These enclaves will contain the airports, the utilities, the banks, and foreign communities. They will be armed camps, like the Army forts in the old west, and will need to be defended against periodic attacks by the indigenous populations outside their walls.

The primary military adversary for the US is likely to be China. China is now the third largest economy in the World, and will soon be the second. They assert claims on territory outside their borders, and dispute the authenticity of the borders themselves. Small wars on the Chinese borders are very likely. The US will retain its technological superiority to the Chinese for the foreseeable future, so direct conflict is unlikely, but conflicts through client states (Taiwan, Vietnam, Thailand, India) are likely to occur. These conflicts will carry with them the threat of nuclear escalation. US-China relations in the next fifty years may well follow the pattern of the Cold War with the Soviet Union. The Chinese will continue to modify their economic system as they grow, so a collapse of the empire from within for economic reasons may be less likely in their case. However, like the Soviet Union, the Chinese empire is made up of a number of ethnic groups. Some, like Tibet, are essentially captive nations. Others have been part of the Chinese empire for a long time, but still preserve their unique cultures and identity. There is an implicit tension between the political center in Beijing and the economic centers in Shanghai and Hong Kong. The political fragmentation of China during the next fifty years remains a definite possibility.

What about military technology? Clearly, all kinds of information and communications technology will be available at low cost, essentially to everyone. Space assets, backed up by airborne platforms, will provide continuous surveillance on demand anywhere in the world. Because so many conflicts will be sub-national, involving a battle space in which civilians are going about their daily business, as in Sarajevo, precision-guided munitions will be extremely valuable. One way to fight an insurrection or civil war is to remove its leaders. Precision attacks on individual leaders are likely to become more prevalent, and more successful. Emphasis will be placed on remote surveillance devices, using robotics and other intelligent machines.

It will be absolutely critical to establish complete air superiority early in any conflict. The only effective defense against air-to-air missiles will be to prevent them from ever being launched. Similarly, ground-based radars must be suppressed to prevent launch of ground-to-air missiles, which will become very effective. In response, more sophisticated radar systems capable of defeating detection and suppression are likely to be developed. Where national governments are involved (as opposed to guerrilla movements or insurrections), non-destructive weaponry will be deployed, which will be able to shut down the electric power grid and all optical, microwave and radio-frequency communications, without destroying the underlying physical infrastructure. This will greatly simplify the reconstruction of the nation after its defeat, and will be more acceptable as a "slap on the hand" of an aggressor, since civilian casualties will be minimized.

Similarly, a high premium will be placed on techniques to deny access to space-based assets, especially those that are shared by commercial users. We would like to be able to deny access to these assets while not causing physical destruction, or even interfering with their general commercial use. At the very least, if we need to shut down these systems temporarily in time of conflict, we want to be able to bring them back on line quickly and cheaply.

In summary, the world of the next fifty years is a very dangerous place, anarchic, rebellious, and heavily armed. While we must be prepared for a direct confrontation with China, we will be confronted by a continual sequence of brush fire wars and civil disorders, abroad and in our own country. Population control and the fear of epidemic diseases will become major issues in world politics. We cannot predict the specific technologies which will emerge with any certainty, but we can usefully speculate on generic technologies, based on what we perceive as the demands to be met.

Vistas of New Capabilities

One way of framing *possibilities* in the future is in terms of technology. By definition, and practice, technology is a manner of accomplishing a task; a means to an end. This essay will provide a different perspective; *possibilities* will be framed in terms of ends—much better ways of accomplishing important operational tasks—better in terms of faster, more reliably, with less risk, with less collateral effects, and with fewer forces. In a few words—we aspire to completely dominate the battlefield.

Vistas of Capabilities

(The Challenge Is to Find Much Better Ways of Accomplishing Familiar Tasks)

The *tasks to accomplish*:

- We must always know of the activities of the enemy and deny the reverse.
- If enemy forces move on the ground in forbidden areas, they will die before they reach their objective.
- If enemy forces occupy territory or bases in forbidden areas, we will promptly destroy them or cause them to leave.
- If enemy aircraft (or UAVs) fly in forbidden areas, they die before they can escape.
- If enemy ships or submarines operate in forbidden waters, they will die.
- If enemy spacecraft operate in forbidden ways, they will be neutralized.
- If the enemy conducts forbidden operations at spaceports, the spaceports will be destroyed.
- If enemy aircraft are deployed on forbidden bases, the bases (and aircraft) will be destroyed; or, alternatively, if aircraft are operated from forbidden bases, the base (and aircraft) will be destroyed.
- If enemy ships are deployed in forbidden ports, they will die.
- Any radar will be neutralized before it can complete the engagement on the target aircraft or UAV.
- The operators that turn on a radar or launch a SAM in this area will die—you cannot launch and scoot.
- The gunners that fire weapons (rifles, artillery, mortars) in this area will die—you cannot successfully shoot and hide.
- If you produce weapons of mass destruction (and associated delivery systems) they will be identified and destroyed.
- Any ballistic missile that is launched will be destroyed/neutralized prior to dispensing submunitions (and over your territory).
- Any cruise missile that is launched will be destroyed before it can exit your country.

- The operators that launch offensive missiles will not live to launch another—we will get the launch crew (and launcher) before they can escape.
- We will be able to respond quickly and decisively and begin and sustain high-intensity operations as required—anytime and anywhere.
- We can do all of the above quickly and decisively, with little risk, and with minimal collateral effects; and thus our enemies perceive that our response is credible, if not automatic. Our Armed Forces are to be totally feared by any would-be enemy—leaders and troops alike. And quite respected by our allies and friends.

Some Remarks About These Vistas

One challenge is that we be able to quickly neutralize the operations of enemy units—so that these operations by the enemy can do little harm or no harm at all. Also, these statements present the challenge that our capabilities are to impart a sense of fear, coercion, deterrence, or paralysis down to the operator level. We should strive to make enemy operators think about the consequences of carrying out assigned missions or functions. The Iraqi pilot, when cleared for takeoff, flies North because he believes that if he flies South he will die.

We desire that the operational concepts to accomplish these tasks be robust and relevant across the spectrum of missions of the Armed Forces, across the types of conflict in which these forces are engaged, and across the environments in which these forces operate. In some cases, this may be fairly straightforward. For example, take the task of neutralizing/destroying a SAM radar before that radar can complete its "engagement." The operational concept(s) for accomplishing this task would be relevant in many different circumstances: (1) protecting a strike package to downtown Baghdad; or (2) protecting an F-16 flying over Bosnia; or (3) protecting helicopters on a rescue mission; or (4) protecting C-130s engaged in delivering supplies in humanitarian relief; or (5) protecting UAVs conducting surveillance of enemy activities; or (6) protecting strike aircraft engaged in halting an invading army; and so on. On the other hand, the operational concept(s) for controlling movements on the ground are not likely to be robust over different scenarios and environments; and these differences must be taken into account in developing concepts for this task.

The conceivers, in formulating and defining operational concepts, must focus on dynamic engagement control—the interaction of several players: sensors, situation assessors, controllers, shooters, and, as well, assessors as to the results of our actions. More specifically, the challenge is to define concepts that make the time loops as short as possible—time starts when a sensor observes the beginning of an enemy operation; time ends when the enemy succeeds or when we neutralize their operation—hopefully, the latter.

In Summary

Vistas of the future has been framed in terms of ends to achieve—in this case how to accomplish important operational tasks in much better ways. The tasks themselves are familiar and enduring. What we seek is innovative ways (if not revolutionary ways) of doing them much better—better in the sense of faster, more reliably, with less risk, with less collateral effects, with fewer forces, and across all types of conflicts and environments.

If we can formulate, define, and finally implement, concepts to accomplish these tasks in the manner described, then we possess the capability to control the activities of all forces—whether they be enemy land forces, enemy naval forces, enemy air forces, or enemy space forces. And being able to dominate the battlefield—completely and decisively—is indeed central to carrying out the common missions of the Armed Forces:

- Protecting the vital interests of the United States.
  - Especially from major regional aggressors
- Maintaining stability and promoting world order. Causing and enforcing a cessation of military operations among warring and recalcitrant factions.
  - Keeping an established peace among wary and untrustful nations
- And, as well, advancing our enduring values and interests
  - Promoting democracy
  - Providing relief in disasters
  - Helping the poor

Fifty Years From Now...

Fifty years from now the Air Force will almost certainly operate in entirely different ways than it does today, but it is likely that the basic missions such as air control, strike, surveillance, etc., will be similar. Unlike today, where our primary potential enemies are second or third world countries, the future will see the emergence of economically and technologically potent rivals - such as Japan would be today if it had the political and cultural mind set of 1939. Here are the critical differences that I see:

1. Strike: Ground attack will employ very long range standoff weapons, launched from inexpensive, low performance, high payload aircraft, loitering well outside air defenses (500 plus km away from target). Against fixed targets the weapons will be inertially guided, based on GPS-type data. Against mobile targets, GPS will be used for midcourse guidance and a terminal homing sensor capable of searching a limited area and identifying targets will be employed in the end game. The weapons will be capable of hypersonic flyout (Mach 10), using either solid fuel rockets or ramjet propulsion. Weapon costs will be constrained by advanced manufacturing technology and by inexpensive very high power computation capability.

2. Air control: Weapons similar to the ground attack weapons will be employed for long range air control, with terminal hit-to-kill guidance capable of hit point selection on the target and employing kinetic kill. These weapons will also be launched from long range by cargo-type aircraft.

3. Battlefield presence: Standoff weapons won't do it all, and it will still be necessary to have aircraft over the battlefield to manage high pace, short time situations. Pilots will control these aircraft from a safe distance via virtual presence. Effective virtual presence will be supported by vastly improved sensors, communication links, and computers, and much of the effort in flying the aircraft, finding targets, and attacking them will be automated. The "pilot-operators" will function in an executive oversight role. The aircraft, freed from the overhead of carrying and protecting a human, will be much more robust and agile than today's aircraft, but also much cheaper. I don't see a need for manned, high performance, expensive aircraft in the Air Force of 2045. The sensors of that time frame will permit a virtual operator to perform the job better.

4. Quick response: A limited inventory of very long range strike weapons will be maintained to provide prompt response to emergency situations. These will be able to reach 10,000 km in less than an hour (either ballistic or hypersonic ramjet propulsion) and carry enough payload to disable a bridge.

5. Space control: The control of space will be central to combat operations in 50 years, and a sizable fraction of the budget will go toward that end. We must be able to guarantee our own freedom of operations in space, and to deny at will an enemy's. This will require the deployment of antisatellite weapons, and the development of protection for our own satellites. Laser weapons, based on the

ground, in aircraft, and in space will be an important part of space control. Affordable space launch is the key to space control, and it is unlikely that multistage rockets will be the answer that emerges. Probably the answer will be in the form of the aerospace plane.

6. Control of the electronic combat space: We must be able to sense and communicate at will, and to deny this capability to an enemy. Advanced technology in RF/ microwave generators, antennas, and damage resistant components will be key to this capability. RF and microwave weapons will be widely employed, including a role in aircraft self defense. Theater-wide emission management will be required. Laser communications will be selectively, but critically employed. This is an area where we should do well, but we will have to give it more priority than it has received in the past if we expect to dominate - as we must. This will continue to be a technology driven, escalating measure-countermeasure competition.

7. Information warfare: Defeating the enemy by contaminating his computer, control, and data systems will be a major feature in warfare fifty years from now, including the air war. Nasty surprises are possible here, and it would serve us well to invest for our technical superiority.

8. Space based lasers: Fifty years from now the technical limitations of laser and optical technology will have been largely relieved, and high power weapons capable of destroying soft targets down to the ground or cloud tops will be deployed. Magazine flexibility will have been achieved, either by inexpensive refueling in space or by solar power, and it will be practical to employ lasers against a wide variety of inexpensive targets, including, to a limited extent, people. Targets that are nominally hard, such as armored vehicles or ships will be vulnerable at critical points where heating, melting or welding can accomplish a functional kill.

9. Surveillance: Detailed three dimensional mapping of the battlefield will be feasible with advanced sensors and processing. Multiple transmitters and receivers in the air, on the ground, and in space, with their signals processed in common (array processing) will yield data and detail in near real time far beyond our current capabilities, or even our imaginings. Computer processing millions of times more powerful than today's will be required, and will be available, and very broad bandwidth communications will support the integration of the sensors.

Resources and the World of 2045

History tells us that the dominant characteristics of human society and its activities, including warfare, have always been determined by the nature and availability of a few critical resources. Obviously, food is the primary such resource, and societies from primitive hunter-gatherers to the Roman Empire to European feudalism have been shaped by the imperative to obtain enough food for the population. Leaders from tribal chiefs to Pharaohs have legitimized their authority on the basis of providing food for their people. The ramifications are endless; as one example, the market for spices to enliven bland diets was a major economic driver of European exploration and colonialism.

The other dominant resource in past ages has been physical technology, largely metallurgy. The fact that we simplify pre- and early history into "stone," "bronze," and "iron" ages testifies to this. A third fundamental resource, related to both of these, has been the domestication of animals, both for food and as a means of advantage in war. Other resources, especially writing, the start of "information technology," have been important, but not overwhelmingly so; unfettered barbarians have conquered sophisticated but decadent civilizations with some regularity.

It is the thesis of this essay that the fundamental resource drivers of human society have changed. Beginning with the Industrial Revolution, the dominant resource influencing society has increasingly come to be energy. Developed nations can now enjoy abundant, diverse food supplies with the labor of a tiny fraction of their populations. Entirely new materials technologies are progressively replacing metals. Transportation and communications technologies are profoundly revising social structures, starting with the family and tribe, that have endured for millennia. The common thread in these many revolutions is energy. In recent decades, access to the current dominant energy source, oil, has profoundly altered geopolitical patterns, and threats to oil supplies have been a prominent cause of warfare and determinant of strategy since at least WW II.

The other resource which has come to exercise a power out of all proportion to its historical role is information. Because it is so pervasive, and has such leverage on the cost and effectiveness of virtually every organized human activity, information has come to be valued as a good in itself and to be seen as a strategic consideration in warfare, both in facilitating one's own operations and in disrupting those of an opponent. We have reached a state where energy and information are absolutely indispensable to the conduct of human affairs and to the maintenance of stable societies. Interruption in the supply of either would thus have the same destabilizing effect as an interruption in the flow of grain from Egypt threatened to the late Roman empire.

The central question in examining the impact of these trends on the future of society and conflict is whether energy and information will be abundant, cheap, and safe to use. Fossil fuels are expensive, polluting, and increasingly scarce. Information is only useful today to those with the equipment, training, and access to sources necessary to acquire it. But these constraints are unlikely to persist, given the huge economic motivations involved and the rapid progress of technology. For purposes of the present argument, assume that fusion, large scale solar conversion, or some other revolutionary technology makes available essentially unlimited supplies of clean energy at little or no cost beyond initial R&D and capital plant investments. Similarly assume that the explosive growth in information processing and networking technology makes great

information resources available to anyone who wants them. It is then possible to consider a society, perhaps as soon as 50 years from now, very different from the present world order.

As the means of producing the goods and services consumed by populations become more mechanized and automated, there will be wrenching changes in societal structures:

- Fewer and fewer potential workers will actually need to work in order to accomplish this production. Thus traditional methods of allocating rewards on the basis of employment and achievement will break down. Holding a job may become a treasured privilege instead of an unpleasant necessity. Disparities between "haves" whose work is valued and rewarded and the much larger number of "have-nots" will grow and be exacerbated by crowding as populations increase. This will lead to social unrest unless education, distribution of goods, access to recreation and health care, and other determinants of quality of life are somehow made universally available.

- Disparities in wealth and prosperity between nations which have access to energy and information and those which do not will increase, creating jealousies that manifest themselves in violence, especially terrorism. At the same time, vulnerabilities due to overseas sources of strategic materials will decrease, since energy abundance will make possible widespread substitution. National interests in other parts of the world will thus be dominated by assured access to markets and by security concerns based on the potential of less fortunate peoples to steal or disrupt the affluence they envy. The developed world could become a fortress of affluence, holding the less developed world in line through a combination of rationed access to technology and threats of military power.

This, in turn, suggests some likely characteristics of the military forces that will be needed to defend those national interests:

- Distinctions between police and military organizations, especially in terms of organization, training, and equipment, will blur and perhaps disappear as the most frequent use of armed organizations becomes pacification, counter-terrorism, and the apprehension or elimination of individuals or groups which threaten or commit damage.

- The ability to gather and interpret volumes of information which are currently unimaginable will become absolutely essential. Global surveillance and intelligence collection will be tasked to achieve currently inconceivable levels of precision in identifying individual criminals in large cities or a single terrorist aircraft in crowded skies.

- Means of swift, sure incapacitation of individuals and groups to halt hostile acts and give authorities the opportunity to deal with perpetrators and provocateurs will be essential and frequently used.

- Means of effective, truly surgical destruction of specific assets of groups and nations either to prevent their use or in retaliation will be similarly routine and essential.

In summary, the armed forces of 2045 are likely to resemble the special operations forces of today, retaining some level of ability to conduct strategic operations and fight set piece battles, but with most personnel and resources devoted to maintaining the security of a largely self sufficient nation against others who covet its riches.

Just in Time Weapon Systems

Development in Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) systems can allow custom designed weapon systems to replace large inventories of general purpose weapons to reduce the cost associated with a large inventory. This Air Force might be able to order up aircraft, with associated sensors, avionics, weapons and communications links tuned to a particular theater with the mix of environments, defenses and targets. The goal would be improved performance, coming from better tuning, with drastically reduced infrastructure cost. Training would be done by virtual reality, allowing weapon system and tactical development to merge. The only hardware the Air Force would need to buy on a routine basis would be intelligence gathering equipment. This hardware would support the work of virtual designers and warfighters. Their work would be turned into real hardware only in the event of a war.

For this to happen, CAD/CAM technology must advance to the point that we would have confidence in the performance of the hardware without test. The virtual reality training must similarly improve. The logistics train, which has vanished during peacetime, must be able to spring to life for an extremely intense burst of activity. The production must be extremely fast. In addition to technical development certain political developments are necessary. These include a mechanism to hold some of the peacetime savings to pay for the custom Air Force, and contracting vehicles to allow the rapid response.

Air Force 2045

The US Air Force in 2045 is one player fully integrated into all aspects of the Department of Defense (DOD) led, United Nations (UN) supported network of specialized and general purpose task forces. They are noted especially for their consistency and professionalism in conducting surprise, surgical, first-time accurate operations across the spectrum from small special operations to large scale, long distance deployments ready for rapid attack.

The Air Force relies on extraordinary people—superbly talented and trained—who operate as integral components in warfare systems of immense complexity. All weather, day and night sensors cover the Earth and can be focused selectively in areas of interest to obtain information about area and spot targets. Sensors feed a network of processing, fusion and intelligent interpretation so that no chemical, biological, or radiological weapons go unmarked, untracked or undetected. Information files, augmented by other data, provide ID of potential targets at various levels of resolution worldwide.

Targeting systems determine the mix of lethal and non-lethal weapons for given missions. Weapon delivery platforms are adaptable to accommodate modular weapons, accept crew or unmanned controllers, and to be tailored for specific, singular missions or equipped for general, adaptive missions.

Human intelligence (and in some cockpits, human physical capability) is enhanced through chemicals, surgery or direct simulation via on-board devices. Information content, human (or simulated/artificial human) response and system automated functions are dynamically blended to the point that performance is often described as "super human," uncanny, with speed, accuracy, and agility beyond comprehension.

Many unmanned, miniaturized vehicles with sensors, small but powerful payloads, and of low cost dominate the near-surface arena. They act to keep us informed and to deliver appropriate payloads/weapons while they keep the adversary confused and falsely informed.

The altitude, Mach number performance envelope of air breathing vehicles has been greatly expanded; e.g. very low q, very high altitude (100,000 ft), long endurance platforms; very high speed (hypersonic), long range missiles, attack platforms and sensor platforms exist (current capability reaches Mach 15). New aerodynamic and propulsive systems enable vehicles at the edges of the new envelopes. New materials and structural concepts focus on low cost.

All vehicles benefit from design and development cycles which are short and low cost. Lean manufacturing concepts, designed-in, allow for few-of-a-kind vehicles at low cost, thus more of the fleet is state-of-the-art.

Most of the technology is commercial state-of-the-art (especially avionics hardware and software), the synthesis of it into military systems is militarily unique and without equal anywhere in the world. Technology integration is the key to this future.

The World in 2045

The world is very different in 2045. After the big war in 2015 which killed millions of people, the survivors established a markedly different political order. The new technologies in communication and transportation reduced the needs for centralized governments, and provided the medium for a single world top administration with appropriate checks and balances. The individual governments were willing to cede authority to a central regime as a result of their revulsion of war and their confidence in the transparency that new sensors and communications nets provide worldwide. The primary functions of the new world government are to maintain the communications and transportation networks, to provide a police force to correct breaches to the peace, and to ensure the sanctity of contracts. Countries are smaller (the U.S. has broken into three countries, Mexico into two, Italy into two, Russia into six, China into eight, etc.). These governments provide all other needed services (which are kept to a minimum). Gold has been re-adopted as the international medium of exchange and private banks provide currency in every country.

There is no longer a military function; only a police force. Every country has an Information Center as one of its primary operating departments. This center is responsible for making all the networks operate, and also for monitoring all other countries worldwide so that if rogue elements develop they can be quickly identified and dealt with. Computers operate by aural means; a verbal mike accomplishes all inputs that cannot be scanned or electronically entered. Outputs are available either aurally, on a tube, or as a print out. The biggest advance has been in development of scanning protocols which are available to everyone. These permit identification of a subject, definitions of search boundaries, and desired output form. The worldwide data bases can be quickly scanned and appropriate output generated.

Communication continues to be available to everyone, everywhere. The satellite networks, fiber optical cables, and numerous switching centers combined with biosensors make it possible to communicate through a headband at any time.

New energy sources have been developed and oil became a drug on the market. The ability to tap atomic energy easily and cleanly is a boon. With the new energy sources came the ability to control force fields (gravity, etc.) and hence opened up new transportation capabilities.

The big change was full implementation of three dimensional travel. Individuals have replaced automobiles operating on roads with small aircars which take them anywhere up to fifty miles. These aircars operate below 5000 feet and are operated between homes, business, malls, recreation centers, etc. They are small (two people, although a special family version is available). The driver enters the destination into the vehicle control system, gets the appropriate coordinates established and then the computers set up the desired flight plan (route, altitude, other traffic, etc.). Thirty seconds before departure there is a warning of the impending event. Transit speeds may reach as high as 300 mph. For longer distances it is necessary to go to a hub where the passenger switches to an airbus which will travel up to 500 miles (and at altitudes of 5000 to 25000 feet). For travel between 500 and 5000 miles force-field powered airplanes travel at altitudes of 25000 to 60,000 feet at speeds up to Mach 4. Longer travel is accomplished by hypersonic vehicles.

The colony on the moon is progressing well. They are self sufficient in general, although make up water is required every two or three months. The unique manufacturing processes which have developed are steadily expanding and producing new products. Planning is under way for the first colony on Mars.

Domestic life both on earth and in the moon colony has changed. The basic political unit is considered to be a man and wife plus children under 21. These units possess full civic rights and are designated as Primaries. Others are Secondaries and as such not eligible to hold public office, lead major enterprises, etc. Secondaries are also required to pay higher taxes. One major enterprise of the family is religion. Religion reasserted itself strongly after the war, but large church organizations are not permitted. A loose confederation within a country is the largest church body allowed.

The education system has been restructured so that all secondary learning is accomplished in the home. The use of computer systems makes this easy, although much emphasis is still placed on personal reading and writing. University level teaching is done at some campuses, but courses still can be taken by computer (and simulator). Advanced degree work is done strictly on a mentoring basis.

The retail distribution system is totally computer controlled. Every city has an underground distribution system which is capable of delivering everything except large, heavy or bulky items. Just as bar coding had revolutionized retailing in the 80's and 90's, its extension to standardized packaging and delivery revamped distribution. This led to the building of the underground networks with associated scanners and controls. Every house and apartment has a delivery port. All routine shopping can be done on the screen, selections made, money transferred, and delivery no later than next day accomplished. Certain hours of the day are reserved for collection instead of distribution. During these periods items can be returned, mail can be sent, or garbage disposed.

In 2045 the challenges are in Space, and in the Biomedical area where efforts to develop adequate physical and ethical checks and balances are still incomplete.

2 July 1995

New World Vistas 2050
An Essay for Gene McCall

I sent my Soul through the Invisible,
Some letter of the After-life to spell.
And after many days my Soul return'd,
And said, "Behold, Myself am Heav'n and Hell."

Ruba'iya't of Omar Khayyam

Tools and technology have continued to evolve for thousands of years and with luck will continue for thousands more. By contrast, in the last 3.5 million years mankind has changed very little. People have remained the same in their mental and physical makeup and in their basic needs, wants, and desires; and these are not likely to change in the next 50 years! In each of us can be found the seeds of good and of evil, of "Heaven and Hell."

Threats to our security come from two directions: those that are people generated; and those that result from natural disasters. The former arise from greed, indifference, ideological differences and economic needs while the latter arise from the vagaries of nature and the world around us (earthquakes, weather, disease, and extraterrestrial threats from asteroids, meteoroids, solar radiation, etc.).

In the next fifty years, while the world as a whole may move toward the realization of the concept of the "global village," human nature is such that special interest groups will continue to form and to generate political and economic unrest to satisfy their own ends. If history is any indication, these special interest groups will use any means at their disposal to reach their end objectives. To preserve our chosen way of life, it will be mandatory that a strong defensive posture be maintained.

As world wide audio visual communication capabilities increase, regional conflicts and "police" actions will be viewed in real time on Cable News Network (CNN) and on the nightly news. Massive battles between superpowers will become less likely but world wide conflicts initiated by special interest groups will increase. These special interest groups could be multi-national in scope and will likely be interwoven into the very fabric of society. They will not necessarily be confined to one specific geographic location. Protection from, and the neutralization of, groups willing to hold people and resources hostage to their demands will continue to be needed as long as people populate the Earth.

In the world of 2050 the high visibility of actions and counteractions will place a great premium upon the ability to humanely deal with conflict situations. This will require weapons that neutralize rather than destroy and incapacitate rather than maim. Rapid response and surgical strikes will be the norm.

In the case of natural disasters the discipline, resources, and organization of a military command will continue to offer the fastest and most direct response for meeting the needs of the victims. Response mechanisms could range from massive energy releases to counter the threat

of an asteroid or meteoroid strike, to weather modification, or to the rapid transport of people, equipment, and supplies wherever needed.

Thus the mission requirements of the Air Force of the future in terms of transport, reconnaissance, surveillance, interdiction, weapons delivery, and the maintenance of global reach and global power may not differ too much from those of today. The tools however will change. Sophisticated multi-spectral sensors, stealth technology, high performance vehicles and non-lethal neutralization weapons will be required. The desire to minimize risks to aircrew and to keep them out of harm's way will place much greater emphasis on the operational use of remotely controlled unmanned vehicles for all classes of missions.

Some potential developments during the next 50 years might be the following:

- The ability to provide on demand real time high resolution multispectral global surveillance.
- The ability to identify the unique spectral signatures of individual humans as well as other organic matter, in a manner analogous to fingerprinting and DNA testing and to do so from remote sensors.
- The ability to communicate directly to designated individuals, perhaps through bone conduction or through direct stimulation of the basilar membrane or the auditory cortex without the limitations of conventional communication equipment. (The USAF's Armstrong Laboratory has done some research already on the "Radio Frequency Auditory Effect" wherein RF sources are modulated to produce voice communications without the use of acoustic media or radio receivers.)
- The ability to project the virtual presence of people and machines through holographic means at any geographic location.
- The ability to destroy weapons at launch whether located on the ground, in the atmosphere, or space based.
- The ability to rapidly train skilled personnel using total immersion techniques.
- The ability to automate the manufacture of any component or replacement part from raw materials to finished product with minimal human involvement.
- The ability to project high energy beamed weapons from space.
- The ability to beam power from one location to another; space to space, space to ground, ground to ground, ground to space.
- The ability to place payloads in space at a cost of $100/pound or less.
- The ability to dominate and control operations beyond the Earth's atmosphere.

Of all the threats facing the peoples of the world in the next century, however, perhaps the greatest is the unrest caused by widespread hunger, malnutrition and extreme poverty. Only after the most basic standard-of-living needs are met can progress be made in education and in the development of civilized and rational behavior. Interestingly, at the present time there is more than enough arable land to adequately provide for the needs of the entire world's population in the year 2050. The real problem is timely distribution—being able to rapidly and economically

deliver food from the regions where it can be grown to the regions where the greatest need exists. Perhaps the major contribution of the United States Air Force to world peace in the year 2050 may be the legacy it will leave in the technology for bulk transport of goods and supplies to underdeveloped regions of the world. The technology developed for the C-17 and follow on programs may prove to be the greatest contribution to world security of all.

New World Vistas

Interviews...

Views of The Future

Introduction

As part of the *New World Vistas* forecast, the Scientific Advisory Board also inherited the responsibility for producing a video program which might represent the importance of technology within the Air Force to the civilian world. The task was assigned to the Air Force Television branch at the Pentagon. Included on the production staff was one historian (Major Dik Daso, USAF), one former network science editor (Mr. Jim Slade), and one experienced producer (Mr. John Primm). The team decided that a vital part of the program should be the futuristic views of SAB scientists, civilian scientists, military men, and other innovative thinkers. Not only were these interviews incorporated into the final video project, they were also reviewed by many SAB members who participated in the study.

Included as interviewees are a Nobel Laureate in Chemistry, the Air Force Chief of Staff, the Secretary of the Air Force, the Air Force Chief Scientist, a RAND Project Air Force representative, leading edge virtual reality scientists, and former SAB members. Their candid views offer a fascinating look into what the future of American Air Forces might be. These are excerpts from each individual interview centering, where possible, on the future.

Limited editing has been done for readability only. These interviews are the actual words spoken by the participants.

Dr. Alvin Toffler

"New World Vistas"

16 May 1995, Washington, D.C.

Q: Dr. Toffler, we're in an amazing period here. We've had an explosion that's almost beyond comprehension. What does it bode for us? Is it all positive, or does it have its negative side?

A: No, we're going through what my wife Heidi and I call a civilizational upheaval. That is, it's not just a matter of technology that's changing, although it is changing in a revolutionary way, and driving a lot of other things. But other things also drive the technology. There's a feedback between society and technology. All of these things are changing.

We're changing family structure, we're changing the way we think, we're changing culture, we're changing business, we're changing how we organize institutions—all of these things at the same time.

When something as big as that occurs, and occurs more or less simultaneously, if you think in historical terms, You can't make changes on that scale without anticipating conflict and without anticipating bad things along with good things.

We have, essentially, a bittersweet view of the world. I think we're moving into a period where our lives and our society are going to be dramatically different from today, but it's going to be very hard. Society is going to be very different, and it will be our kids who decide whether it's good or bad, with a set of values which may diverge somewhat from our own.

So I don't think this enormous technological explosion is all positive, but I also don't share the lead-eyed view that it's going to destroy the world and it's terrible and people who do this are bad. It's ridiculous.

Q: So a societal change. When did it begin?

A: As you know, my wife and I use kind of simplified terminology. We speak about first wave, second wave, and third wave. The first wave was the agrarian revolution which occurred maybe 10,000 years ago. The second wave of change was the industrialization process starting 300 years ago. Now we talk about a third wave of change. We think that it began somewhere around the mid 1950s, after World War II, and that it was associated with the development of the earliest civilian uses of the computer. But also, that came within two or three years of a tipping point, a very important socioeconomic tipping point in American life.

1956 was the year when for the first time white collar and service workers outnumbered blue collar factory workers. That proportion has been changing ever since. We've more and more "knowledged" workers and fewer and fewer physical workers, at least in proportion to one another. We think that was a very important indicator of where things were going to start going.

Within that period, between 1955 and 1960, look what happened. Almost unnoticed by the political leaders of our country and by most Americans who didn't see them as related to one another, you had first, the earliest civilian uses of the computer, but you also had the introduction of commercial jet aviation. You had the universalization of television. And more important than all of that, you had the introduction of the birth control pill. On October 4, 1957, which happened to be my birthday, Sputnik went up.

So within a five year period you had these massive technological changes or events, and they began to fit together with other changes taking place, and I think we started to roll and began to move out of a classical industrial period roughly in the late 1950s.

Q: But look how long it took us to get out of the agrarian period.

A: It took us 10,000 years, yes.

Q: This has happened within a period. in your life time, five or six years.

A: Exactly. And that's why the central fact of our existence is acceleration. Everything has been moving faster and faster and faster. History is moving faster. It's not just that we can have a new generation of computers in six months, but that all these other things are impacted, and themselves impact on the technological system and demand responses.

The consequence of all of that is what we call future shock, and if you look at many of our political decisions they provide evidence of future shock. That is, we try to make too many decisions too fast about things that are too complex, and by the time the decision is made, the phenomena is already gone. That's not a good way to handle a system. But indeed, I think that's the case. I think it's the case in many countries—not just our own.

Q: So you don't describe the computer as a spring board. It's more of a tool and a resource.

A: It's both. It also changes. Early on, the Soviets had the idea that they were having trouble managing their centrally planned economy. They couldn't get enough information. They didn't know how to handle the information about how many pairs of shoes were produced. They had another problem, and that is that the information coming up from the managers were mostly false because they were afraid for their lives to tell them we didn't fulfill the quota. But that's another story. The fact is, they just couldn't handle the complexity of the economy.

When the first mainframes came along, they said, "Ooh, boy," now we can do it. We're going to get all this information, and we're going to now be able to manage the economy centrally.

The fact they overlooked is that the computer does not simply help you manage large amounts of information and complexity, it creates complexity at the same time.

So we're in a sort of positive feedback loop in which we are at one and the same time trying to master all of this information, master all of this complexity of decisionmaking that we're coping with, and at the same time, generating more complexity, more diversity, more

internal differentiation in the system. I believe that's happening not only at the level of the country and the society as a whole, but also within institutions. So it's happening in the Air Force, it's happening in the Congress, and it's happening in corporations.

Q: We may be fooling ourselves by thinking we're making computers simpler. Are we only delaying the inevitable.

A: Well, one does hope we make them simpler so that we don't have to spend days with a custom programmer to export a Rollidex from this machine to that machine which is still, unfortunately all too often the case.

Q: Are we in a stage right now reminiscent of the end of World War II when we had the atomic bomb, and we thought we were the big dog on the block, and we have the upper hand because we have this weapon. We think our technology is so superior at this point—not recognizing the fact that anybody can go out and buy this technology. You're not stealing atomic secrets now. You can go buy this off the shelf. Is that right?

A: Right. You buy it in Radio Shack or buy it in a discount store in Hong Kong. I think that we are kidding ourselves if we think that we are the sole exclusive possessors of all of this wonderful information technology. It is spreading rapidly all over the world. Let me give you an example.

If you ask most Americans where is the biggest computer and electronics show in the world held, many of them would know that it's COMDEX and it's held in Las Vegas. But if you ask them where was the second biggest show is held, and I've done this, the answer comes back, "Japan, Singapore." Wrong. The answer is Brazil, Sao Paolo. My wife and I gave the keynote at the world's second largest COMDEX. Hundreds of thousands of people going through that place. We're manufacturing electronic components literally in the dead center of the Amazon, in Manaos. And this is happening in other parts of the world.

Silicon Valley is buying software from Bangalore, India. And Bangalore is buying it from Vietnam.

So the idea that we are the monopoly, that we have a permanent monopoly on high tech or information technology is one of those ideas that can really get us in trouble.

Q: So what do we have to do to maintain an edge?

A: Now it comes down to a set of sort of cliche's. We've got to be smarter and faster than anybody else. We've got to think more deeply. We've got to innovate more. But all of these are kind of clichés. How do you do that? It's very difficult.

You're asking me a question I have to answer with a joke. The ant, all summer long, was putting food away but the grasshopper was playing. As winter came, suddenly it struck the grasshopper it was going to starve. So it asked the ant what to do. The ant said, "Go talk to the owl. The owl is a very wise bird."

So the grasshopper goes to the owl, and the owl grumpily pays attention to him, and he says, "What do you want?" He said, "I'm going to starve if I don't do something."

The owl says, "It's obvious what you have to do. You've got to become an ant." At which point the grasshopper hops part way and does a doubletake, and then goes back hat in hand and says, "Mr. Owl, how do I become an ant?"

The owl says, "I give policy advice, not technical assistance."

We have to be a smarter, better organized, more far seeing economy, society. We have to have smarter workers. We have to understand that no product lasts forever. No edge lasts forever, and that we're part of a global system, now, in which all of these things are interacting at a very rapid rate.

But we also—and this seems to me is a special point for the military and our intelligence community—we have to look at the world in a new way.

We have grown up in a world in which "threats" were other nations. For most of our life times the Soviet Union was that threat. But it could be some other country. Threats were nations versus nations. Now we're moving into a period when the global system consists of many, many players, not just nations. There are multinational or transnational corporations of a new kind, really responsible to no one country. There are gigantic religious forces that play a role in the international or global affairs—Islam, the Catholic church, and others. There are narcotraffic networks across the world. The world is a really complex place. It's not just nations any more. And a lot of the issues that we have to deal with are what a friend of mine calls intermestic. That is, they're international and domestic at the same time. You can't separate them very well.

This presents a whole new set of challenges, both for our political leadership and for our defense. Even our definition of national security.

Q: It speaks to a whole new form of warfare, if indeed you can use the word warfare. You can see, given in the information age that we're in, that a lot of this could be economic rather than actual physical warfare.

A: Yes. In, *War and Anti-War*, which we wrote about this question of the relationship of information to warfare, the nature of warfare, the way people fight, reflects the way they work. If we are, in fact, creating an information-based economy, we're also creating an information-based military. Just as in the past when we industrialized the economy during the industrial revolution, we industrialized warfare. The machine age gave us the machine gun. Now the information age is giving us the information-based military. The question is, what does that do? How do you deploy that? How do you defend against an attack by some 16 year old sitting halfway around the world who is able to shut down some vital communication system within the United States? It has been pointed out at the School of Information Warfare and Strategy at the National Defense University more than once, you may not even know who the adversary is. So how do you respond?

It raises phenomenal questions. It also says that you need a radically different kind of military. That is to say, when a new form of warfare emerges, it doesn't necessarily eliminate the old forms. We still use a dagger, a bayonet to kill somebody in certain circumstances, but

those become secondary forms of conflict. The primary form of conflict in the industrial age was industrialized. Mass production gave us mass destruction.

Now we're moving into a period that my wife and I call demassification. Societies are becoming internally more different, more differentiated, more complex. We're demassifying the products that we use.

You go to WalMart, there are 110,000 different items in a typical WalMart store. That's made possible by new technology, information-based technology, which permits variety. You go turn on the tube. It's no longer three television channels. You have a choice from an enormous number. Eventually, it will be an infinite number, in effect.

So what's happening is that the mass production society that was created by the industrial revolution is becoming a demassified society, and guess what? Destruction parallels that. So that as we go toward the demassification of production, we also see the potential demassification of destruction, which is another way to describe precision-targeted weaponry. You don't have to wipe out a whole city to get one building. You can send the cruise missile down the air shaft—if you know which air shaft.

Q: But don't you defensibly have to have massive redundancy in order to protect your own system?

A: Exactly. And the United States, because we are the most electronically dependent, and because we have the most advanced and the best computer systems and telecom systems are the most dependent upon them, we're also the most vulnerable to attack. That's something that most Americans do not yet understand.

Therefore, a lot of attention needs to be paid to what one of the speakers of the conference we recently held talked about electronic civil defense. We need to be prepared. And redundancy is one of the ways you protect yourself, but it isn't, obviously, the only way.

Q: If you can shut down this country's information networks, you simply can...

A: You can knock out our hospitals, you can knock out our banking system, you can fix it so companies can't send money to each other, you can't get your pay check. You can knock out our power grid. You can knock out all kinds of central information, information systems or information-run systems, and bring this country to its knees. We are sitting ducks for that.

Q: Look at the society. Look at the society that gets entrenched in this kind of information, in the culture. Is this society necessarily as cohesive as it used to be? Is it more isolated? Is it more easily led because people tend to specialize in information?

A: I think that it is far more diverse than it used to be. Are we fragmenting? Well, the fragmenting is a kind of negative way to describe it. The positive way to describe it is to say we're becoming more richly diverse. If we could manage that diversity, we would get a lot out of it. Diversity helps generate innovation. It helps generate a lot of good things in the society.

On the other hand, you have to be able to manage that diversity so that diversity doesn't become conflict or a nasty conflict within the society. We are no longer a uniform, homogeneous population, and it isn't just ethnic.

One of the problems is, when we talk about diversity, people immediately think about ethnic differences or racial differences. We've got little wars going on between smokers and non-smokers. Those are political differences being fought out in state legislatures around the country. We've got differences between people who have this disease and people who have that disease, and they're fighting over the budget for research for those things, and so on.

So the diversity within our society is enormous, and it is not just along the traditionally recognized lines. That is, in part, a response to the information revolution because the information revolution helps make that possible. It gives everybody information power and gives them ways of identifying with others like themselves who may be different from others and so on.

The information revolution on the one hand promotes and encourages diversity. And the work force, which used to be based on unskilled labor which was interchangeable, and in which people put on a denim shirt and they came to work at the same time and they did the same work day in and day out, that's changed. The work force is highly differentiated now. More occupational specialties, more different skills required, and so forth.

So we are an enormously diverse society in every dimension of the society.

How do you manage that? That becomes a challenge that's the management of high complexity. And believe me, we don't have it. Neither does anybody else. They haven't faced quite this level of complexity yet, but that's the challenge for us.

Q: Does that make us more vulnerable at this point? Are we in a state of confusion or transition? Where are we?

A: We're in a state of creative confusion. And that may be a necessary stage.

We're trying to adapt to a revolutionary new way of life, a new civilization, in fact, at a very rapid rate. And you know, the thing about the industrial revolution is that when the United States began to industrialize, we could look and see how the Brits had done it before. When the Japanese industrialized they could look and see how the Americans did it. We can't look at anybody for a model of where we're going, because nobody's been there. We're the spear point of this third wave revolution. They look at us.

But in fact, each country will have different patterns of development and different ways of adjusting to all of this. There's no model for us simply to follow. We have to invent our future rather than simply copy it from somebody.

Q: And the future can be anything we want it to be?

A: And the future, within a broad range of options, yes, it can. I think we're in the middle of what we would call third wave science—that we now know there's a relationship between chaos and order. Chaos isn't the opposite of order. Chaos gives rise to order. We're now at a

moment of chaos, but out of this will come a new order. Not necessarily one that we have designed by regulation. But in fact, partially influenced by chance events, and by many other players out there who may make an input to something that we've never thought was important for us, which then rebounds through the global system and suddenly has a giant effect on us.

So it's a really challenging, complex moment. We have all the benefits. We have all the pains of living through enormous dislocation in our family structure, our jobs, our employment situation. These are the pains and agonies of going from one kind of civilization to another. But we also have something that very few people in history have had. We live in a moment when in our lifetime we can see and participate in making this revolution.

Most people live in societies that never change—not during their life time. Things change so slowly, they couldn't perceive it.

Q: This has been a dramatic, pivotal century?

A: This has been a fantastic moment.

I'm sure there are historians and people who say they live in a period of change. It has never been global. It has never been as fast as it is today. And the world has never been as compressed as it is today. So this is, in fact, a special moment of history, and of the 80 billion human beings who preceded us on the planet, very few, very few ever experienced anything remotely like what we're living through.

Q: Let me ask you a final question which I'm asking everybody in this series. What do you think the Air Force will look like. What will be its role?

A: What is the role, what is the meaning of national security or security—maybe it's even not national. What is the relationship of violence, wealth, and information as sources of power in society? And what is the mission, therefore, of a military force?

I believe that we will continue to need military force of some kind, but whether that Air Force will need airplanes or what kinds of airplanes...I think it's impossible now to say 50 years ahead what that's going to be.

In the past, if you forecast, you were looking at slow changes. You maybe got some guess at that. But looking 50 years ahead now, so many changes take place in 50 days, that making that long leap is very, very difficult. Therefore, I would be loathe to say what the Air Force would look like. The really dramatic change, you may no longer wear blue.(Laughter)

I don't really have a good answer to that question. It's too specific for me.

I think clearly we're seeing more standoff, deeper strike weapons—not necessarily aircraft. Clearly, space is going to play a much, much larger role in the entire process. But again, I would argue that the central element that the Air Force or any other force will need is much richer and deeper and better information and knowledge, because you can have the best cruise missile in the world that can go through the smallest window, but you've got to know which window to put it in. And you need, therefore, radical changes in our intelligence capabilities.

One of the scary scenarios, of course, which other countries have faced and we have faced in the bloodiest fashion, but because of that have repressed, is the danger of civil conflict. Country after country has faced the problem of internal conflict. We haven't faced that for over 100 years, since the Civil War. But when we did, it was the biggest and bloodiest war in history up until that time. What that was, was a war between a first wave South and a second wave North.

Q: What does it takes to know all, see all? Sensors?

A: Coverage.

Well, I have imagined, and this is purely based on imagination, but I have imagined that we will eventually seed the world with sensors. Maybe they won't be any bigger than an ant. Maybe they'll be quite intelligent and will transmit all kinds of multi-modal or multi-dimensional information. Who knows? That's one possibility.

But I want to say that we are very good at the technology, and we're good at TechInt. We're not as good at HumInt. It seems to me that we're in a world in which we're going to have to know a lot about other cultures. We're going to have to learn other languages or have automatic translation or something. We're going to have to have a lot of human beings reporting back to us if we want to prevent some of the wars of the future and some of the terrorist possibilities of the future.

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Q: Since I saw you last, I think it was two years ago, and we had that fabulous discussion about non-lethal warfare, where has the subject gone?

JANET MORRIS: Non-lethal weapons as a concept and as a reality in the last few years has become a pressing need for this country. Where in 1989 and 1990 when we first began the concept discussion of non-lethal weapons it was all hypothetical, we were predicting the needs of the future. Now, we're facing the needs of the present, and we still haven't built these weapons or trained people to use them.

Q: All right, let's define them. What are they? What do they do? Do they disable people, or do they destroy the enemy's ability to conduct warfare? What do they do?

JANET MORRIS: Non-lethal weapons are weapons that both destroy the enemy's ability to conduct warfare, and temporarily incapacitate people, so that those people do not present a threat. Non-lethal weapons are life conserving, environmentally friendly, and fiscally responsible new weapon systems that really comprise the much-vaunted peace dividend because they're built from mature technology and allow us to maximize profit from investment into technology developed for the Cold War.

Q: Chris, is our technology good enough to do this?

CHRIS MORRIS: Our technology has arrived at a threshold where worldwide we are perceived as being able to mount invisible forces. The kinds of technologies which are capable of winning hearts and minds, which is a term borrowed from the intelligence community, and used to be highly suspect. But more and more our missions now are to, in the full glare of media presence, be able to do missions which involve sensitive extractions of personnel from sites under contention, and the separation of non-combatants and combatants in venues where many innocents are involved.

Q: Give me a specific example. Can you describe a couple of these instruments?

JANET MORRIS: Non-lethal weapons break down into three categories — kinetic, something that you throw; electromagnetic, anything that's powered up; or chemical. Non-lethal weapons such as acoustic beams which are merely perturbations of the air which have a temporary effect, have no chemical residual to pollute the atmosphere, do no lasting damage to the environment.

A number of other electromagnetic systems such as the acoustic weapons, will allow us to make the weapons of the other party to a dispute unworkable, thereby, keeping him from killing us. The real point of non-lethal weapons is to face an enemy whose technology is lower, who may be using lethal force against us, and not have to kill him to protect ourselves or to reach our objective.

Q: And this is possible to do?

JANET MORRIS: It's possible. We have never asked for non-lethal weapons. We have always asked for increasingly lethal weapons. It takes some thinking on the part of military planners, new doctrine which is how we do what we do, new training for the troops, and it has to be done in a way that an overloaded soldier, who already is carrying more than 90 pounds into battle, isn't asked to carry a whole new arsenal of things along with him.

The non-lethal weapons most likely to come into service are going to be the ones that can be used with existing weapons. In other words, a new bullet that is a non-lethal bullet, so that the soldier isn't carrying anything that's extremely bulky, or doesn't have to make a choice. His weapon can give him either a lethal, conventional; or a non-lethal, new, response.

Q: Are these in the labs?

JANET MORRIS: They're in the labs. ARDC, the Armaments Research and Development Command, is really the center of non-lethal weapons development in the United States, and they provided a number of technologies to the Marines for the Somalia extraction. According to the Marine general who oversaw that extraction, even the publicity surrounding the use of non-lethal weapons in Somalia provided a deterrent. In other words, it kept the Somalis from coming out to harass, fight, or even attempt to kill the Americans.

Q: Specifically, what weapon was he referring to?

JANET MORRIS: The Marines had sticky foam, and some non-lethal grenades, and used non-lethal weapons to provide sort of chemical fences, and other new kinds of technologies. They did not, however, as the Somalians feared, have a weapon that invisibly sterilized Somalis.

The fear of a new system may be much more effective than the fear of death against an enemy to whom death is an acceptable risk. We are a casualty intolerant society, trying to bring order among casualty tolerant societies. In many cases the enemies we fight hope that some of their soldiers will die so that they will be martyred, and Americans will be hated and reviled because we've killed their citizens.

Not only do we not want our soldiers to die in battle, we really don't want to kill non-combatants, women and children, and increasingly, we don't want to kill the enemy.

So how do we project force? The answer is, to project overwhelming force that's politically acceptable and provides strong policy supportability. In other words, weapons have to support policy. The military exists to be the sharp end of politics.

Q: Let me make some connections. In other interviews, T.K. Kearney comes to mind, with hyper-war, and John Warden with his concepts of the things you're speaking about. Let's connect this to the Air Force and the Air Force of the future. A lot of what those people are talking about, spacebased weapons. How does that tie in with your theories?

JANET MORRIS: We did some work for the Air Force which led to a paper called "Weapons of Mass Protection." Weapons of mass protection is a concept that says the new mission is to protect the civilized world from barbaric actions of developing states. To protect global trade, to protect rule of law. Some of that will have to be done from space. Information warfare, increased intelligence capability, all of the kinds of air war first operations that politicians increasingly call for, are going to have to be more closely coordinated with ground operations.

Someday, John Warden's dream of having a war in which no soldier's foot has to touch the ground, may be a reality, and if so, a lot of that warfare will be non-lethal because the real targets in that kind of warfare are the infrastructure points of the enemy—his power plants, his communication systems, his electricity. If we can take someone's electricity away until they surrender, and then give it back to them—as the Russians did when Ukraine wanted to keep the fleet, and the Russians turned off the Ukrainians' gas, and within 24 hours, the Ukrainians gave up—then we are non-lethally prosecuting the mission.

We'll never get away from lethal force, but space-based, air-based, ground support missions are going to be the norm because the U.S. is increasingly unwilling to put in ground troops. Ground troops mean the possibility of American casualties and in this current political climate, when we lose people, we pull out. The enemy knows that. So the more we can do without putting people on the ground, the easier it is for us to project U.S. power.

Q: Chris, can you launch non-lethal weaponry from attacking aircraft?

CHRIS MORRIS: Yes. Most significantly there is a movement to involve UAV's—unmanned air vehicles—as platforms for non-lethal effects delivered precisely to very discreet locations. In Sarajevo where you have Sniper Alley, and people operating mortars from the tops of apartment buildings where many innocent participants live, you've got to develop a capability—and we believe air is very effective for this—to deliver precise effects to systems and personnel operating those systems, without involving a larger community.

Q: Give me a specific scenario. What kind of weapon? What would be the effect? How would it work?

CHRIS MORRIS: It's possible now to trace bullets, mortars, and projectiles—whether you can see the source or not—very accurately, using thermal technologies. Acoustics have also

been applied to this problem. The combination of those technologies could offer us in the very near term the capability to shoot back with a center error probable of five centimeters at three miles. With that kind of accuracy, you can deliver non-lethal payloads, you can target for information-gathering purposes the sources of hostile fire, and very quickly transfer that information to strategically placed systems.

Q: ***In effect, the gunman's own bullet becomes a glide slope for your weapons?***

JANET MORRIS: That's right.

CHRIS MORRIS: Exactly.

JANET MORRIS: A technology such as the Lawrence Livermore thermal bullet tracker means that as soon as you fire, you become a target, and the enemy can use your fire to send a responding round right back along that same trajectory. If what you're firing is a mortar on the top of an apartment building on Sarajevo, the main street, we can send a responding missile right down the barrel of your mortar, crack it at the base, without even killing the guy who's operating it or the women and children he brought out with a picnic lunch to watch.

Q: Let's take just a little turn here. With computer technology as it is today, it seems to me that if somebody began to cause you trouble, you could probably shut down his internal workings, close off his bank accounts, and, in effect, stifle his economy overnight without him knowing who did it.

JANET MORRIS: The information warfare technologies of the sort that include computer interruption, banking system interruption, are capable of being fielded whether they constitute acts of war, and as so, unnecessarily provocative, is a different issue.

When we evaluate non-lethal weapon systems, we want systems that are decisive, rather than just provocative. The information warfare area is the area where you have the most problem trying to find systems that could be used alone and not be exceedingly provocative.

In other words, if I shut down your banking system and I'm the U.S. and you're Ghadafi, and we would freeze your assets and you can't get at them, then is that an act of war? Maybe not. But if he did it to us, then we would think it was an act of war. It depends on who's doing the shooting and what the laws are. Non-lethal weapons and information warfare mean that Congress has got to start looking at the definition of an act of war in the technological and information age, and set some ground rules for fighting in this new area. They need to set some ground rules for fighting in an area that is different because the action is taking place between the moment that diplomacy fails and the moment that a shooting war begins. We don't know what to call that area yet.

Q: And it's based on technology that is widely available all over the world. So what's to stop the other guy from doing it to us, except the fact that we're wealthier and deeper?

JANET MORRIS: When the Clinton Administration learned enough about information warfare in a meeting where we were briefing it to understand that one party could zero another

party's bank account, and that money at that level was virtual, they immediately said, "We've got to ban this."

We said, "What do you want to ban? The computer? The modem? The telephone line? Maybe electricity?"

Most of these technologies of which non-lethal systems of information systems are made, are far too proliferate, far too available, to be "bannable," and attempts to stop them are going to fail because anyone who gets a college education in a scientific field can develop from readily available parts, these technologies.

Electromagnetic pulse weapons are the sorts of weapons that might fry your computers or take down your electronics grid. They don't hurt people, but they knock out communications type equipment. And we have a high power microwave expert who says that he can go into a Radio Shack or an electronics store anywhere in the world and buy off the shelf, parts to make a high power microwave weapon.

So the issue for us is developing a lead in these technologies so that as we develop them, we develop the countermeasures that enable us to protect ourselves if these weapons are used against us by people who will not be concerned about what's legal, what's moral, or what's ethical.

Q: That's what comes to mind. Technology can be traded back in our direction. What's our protection from that? Is it being much deeper and more redundant than the other guy? Is that all there is to that?

CHRIS MORRIS: Measures and countermeasures are the chain of research and development leading to finished and fieldable systems. We often ask information warriors what they're going to have the leader of the country they've selected say if they can possess his image and manipulate his voice and image, and they're often at a loss because they haven't done the basic homework which involves studying a culture to find out what its hot buttons are. How to keep them, how to deter them from aggressive activity by using their own communications in a way that they would perceive as not too irregular to be believed. It's a complex problem, and as we venture further into non-lethal systems development generally, we find that the first question is always, what effect do I want to have on my target? How do I want him to respond if I can so define his response?

JANET MORRIS: Technologically, countermeasures and defense against enemy attack using new weapon systems that may be non-lethal or maybe information warfare systems, is an area in which action by our defense community to develop systems is the only way we can get deep enough in expertise to be able to develop countermeasures. When we write recommendations, we say that countermeasures and the antifratricide, which is protecting our own soldiers, has to come up right along with the systems on a moving curve, and that there is no stable point where you stop developing systems any longer. But you also have new kinds of technological issues.

We saw in Somalia that all of our information warfare and C^3I capability was useless against Somali communications. We brought all our sophisticated electronics, and they still were able to tell one another at a distance, exactly when our helicopters took off or where our

planes were going or where our guys were, because they were using drums. Initially, we didn't even have anybody who spoke "drum," and we certainly didn't have an electronic way of interfering with "drum."

So you've got a sort of a reverse curve effect. A high technology may not be what we're facing. We may be perfectly capable of defeating a high technology enemy, but now we've got to be able to defeat a low technology enemy as well.

Q: Hasn't that always been the stumbling block for this mighty nation, that you get attacked by gnats who can bite it pretty badly and all it has is a sledgehammer to swat back?

JANET MORRIS: It's true that we make an assumption that everybody else is just like we are, and if we should interrupt their MTV that they will suffer mightily. But that's not always the case. One of the things we've looked at with non-lethal weapons is providing a way to stop somebody who may be using cultural or tribal weapons. There are enough sticks and stones on the planet to kill everybody three times over, so you'll never have non-lethal warfare. Anyone who talks about non-lethal warfare is not only talking about an oxymoron, but has not thought this thing through.

Lethality his a property of actions of mammals. Mammals kill mammals and everything else. We're not going to be able to stop them technologically.

Killing is a matter of intent. What my intent is when I go into the field. If I want to do it enough, I will find a way to do it, unless you can interfere with either the weapons that I have to do it with, or my intent. The best non-lethal weapons attack intent.

Q: That brings us right back full circle to where we began. Can we do that?

JANET MORRIS: We have the technology to do it. We have no defined enemy now. Our enemy is chaotic. He's little, he's all over the place, he's not coalescing into one big super threat of the sort that we like. We would prefer a monolithic enemy.

Can the U.S. exist militarily without a threat? I have no idea. I hope that we can. Every great empire throughout history—starting with the Egyptian empire, much before the Romans that everyone knows about—has fallen apart when it lost its threat. We are a threat-driven society.

But since we are so globalized, and since American industry is all over the world, and we consider the Americans the same as America—wherever Americans are, that's America to us. We really do have a threat, and that's a threat to global trade and a threat to our ability to enforce rule of law.

A hundred and sixty million people have been killed in the 20th Century through warfare alone—it's a huge number. The amount of dollars spent to win the Cold War are incalculable. The only way to make those losses, both of people and resources, worthwhile, is to now capitalize on what we've won; to be the super power we spent so long becoming. And given our sense of fair play, the sort of Lone Ranger effect—the Americans want to come over the hill, save the farm, send the bad guys away, and go home. We don't think about what happens when the bad guys come back. We're going to have to find a way to enforce a rule of law in an era where the only thing believable is proof.

Q: Let's finish up. What I would like you to do for me is using the biases that you have, design me an Air Force of the future. What's the Air Force going to look like in 2020?

JANET MORRIS: The Air Force in 2020 will have two main capabilities. One will be man piloted, and on-site... i.e., pilots in vehicles that overfly a venue and do something to it. The other will be remotely piloted, pilots that are three to five to maybe ten miles off-site using electronics to pilot small, expendable air vehicles which do specific jobs and can give us a new reach and deep penetration in places where no American casualties will be tolerated. That Air Force will be able to intermittently control the infrastructure of a country with whom we are at war—limit their ability to produce electricity, completely limit their communications, and do it in such a way that when they surrender, we can give them back those capabilities. We won't have to go in and restore the plants. We will have control of their resources without having to destroy them.

CHRIS MORRIS: The Air Force of the future will be able to more convincingly provide no-fly zones, police them, enforce them, conduct blockading and economic sanctions with more capability because of an electronics matrix which will tie directly into the infrastructure capabilities of any targeted adversary. And in the case that he's low tech, provide merely a deterrent based on the world's perception of the superior ability of American technology to control violence.

JANET MORRIS: The Air Force of the future will have new capability to force aircraft down without having to shoot them out of the sky; to keep aircraft on the ground, or force them to veer off using lasers and using sticky foams, so that we can control our airspace better.

The Air Force of the future, if it's the American Air Force or a NATO air force, will be able to create fire-free zones and enforce them where the enemy dare not use any weapon that leaves a heat trail, because that leads to an exposure of his own position.

Q: Then there's space-borne surveillance.

JANET MORRIS: Space surveillance can easily be imagined to reach the level at which we can count the change in your pocket from 22,000 miles up. And fractoral imagery technology will allow us to identify specific combatants by the shapes of their heads, which are as individual as your fingerprint, from the air. So if you're looking for a particular combatant who is in your database, and he's in a crowd, you can identify him from an aircraft flying on station maybe 40,000 miles up.

CHRIS MORRIS: However, there will be a basic change in the Air Force's roles and missions, which will, we believe, tie in parallel, to our globally far-flung economic interests. As nation state sovereignty breaks down, economic sovereignty will emerge to take its place. Protecting those assets worldwide, and the ability and status quo of trade, the conditions supporting global trade are going to become increasingly the focus of our strategic missions.

Q: Aren't world economics really the future core of control?

CHRIS MORRIS: Of course.

JANET MORRIS: Now that the world is so economically interdependent, the military's job as the sharp end of policy and politics is going to be to enforce stability for global trade. Everything has value on the ground. We're not going to be able to allow people to rip up towns and destroy oil reserves and set fires and create ecological disasters, and those will become acts of war in an era where, because of CNN and live in your living room broadcasts, even one American casualty is far too many to take.

So the Air Force, which is right now the first choice of policymakers wherever it's necessary to show U.S. power and project force with minimum risk, is going to have even more pressure put upon it to provide new ways for the U.S. to project that power, to maintain its global lead, without putting soldiers on the ground.

Q: So the great white fleet flies.

JANET MORRIS: The great white fleet flies, and the empire, which will be our equivalent, I suppose, of the great British empire, is going to be an empire of the air.

Colonel T. K. Kearney

Dean of Students
Air Command and Staff College
Montgomery, Alabama

"New World Vistas"

2 May 1995, Maxwell AFB, AL

Q: Colonel, we hear the word "hyper-war." What does it mean?

A: The Gulf War was the first hyper-war. In that conflict, the coalition was able to impose strategic paralysis on an enemy state in a matter of minutes. That same level of effect in World War II took years to accomplish. Technology gives us that capability to compress the time factor and to increase the order of magnitude of the intensity of our first attack. Technology separates hyper-war from everything that came before it.

Q: Are we capable of sustaining that over an indefinite period? Is our technology now capable of carrying on hyper-war as a standard element of warfare?

A: The unique thing about hyper-war is currently there is only one nation on the face of the earth that can conduct hyper-war, and that's the United States. It's our technology that allows us to do that. As our technology expands hyper-war, the intensity will increase. The ability for another nation to catch us, to come up to us, is dependent on our ability to maintain this technological edge over everyone else.

Q: Which technologies do you mean specifically?

A: The primary difference between hyper-war and anything that came before it, is the advent of the computer and what it allows us to do. It makes space travel possible, it makes space systems possible. It allows us to process tremendous amounts of data, and data turned into information is what spells the difference between defeat and victory.

Q: So in essence what you're telling me is we can win war by confusion instead of kill.

A: War is always going to have the physical element. Confusion, the ability to use information to our betterment, is an integral part of today's warfighting. But it has been for thousands of years.

I would never want to try to imagine an information war where it was just thoughts going back and forth. That is probably much too far in the future.

Q: So what you're also saying here is that we have a technology already evolved that can conduct hyper-war. It's going to get better, we all know that. So hyper-war will probably become a basis of American warfare by default.

A: Hyper-war does a number of things for America. It gives us the capability to achieve political objectives without risking vast quantities of our national treasure — either in money or in manpower. Hyper-war will continue. We will continue to refine this capability. But hyper-war is nothing more than the fusion of all of our national capabilities for one political objective.

Q: Are we capable of conducting two hyper-war style operations within two months?

A: Hyper-war does give us more flexibility than what we had before. The number of forces actually engaged will be smaller. We could, perhaps, do more than one at a time. But hyper-war for the first time offers the promise of conventional deterrence—much as we had nuclear deterrence for 40 years.

Q: How do you do that? By getting at the enemy's infrastructure, his intelligence infrastructure, his operational infrastructure, his computer system? How do you do that?

A: Hyper-war focuses on the entire enemy state, from the leadership outward. His fielded forces become not secondary, but less of a problem than they were in the past. We have the ability to hit the enemy and dismantle the enemy where the enemy values it most.

Q: So the big machine behind you, is that going to be obsolete in the hyper-war age? [B-52 in background]

A: The B-52 behind me represents a form of nuclear deterrence. But more important than that, it represented the Air Force's ability to reach out anywhere on the face of the earth to secure national objectives within 24 hours. A platform like this or improved, is at the core of hyper-war. You have to be able to reach out and get to the scene within 24 hours. The distinction between the platform that you see behind me, the B-52, and where we're going, is the difference between air and space. That's an artificial distinction. It's really a continuum that goes from the surface of the earth outward. Technology has allowed us to take advantage of going further out. But in reality, the things we do are the same things we've always done, and they form the core competencies of the Air Force — today and tomorrow.

Q: This brings us to that question about space, and the access you need to simply extend the Air Force's reach into space on an easy access basis. You're really going to have to take the Air Force into space in order to accomplish a lot of this.

A: The first flight of an aircraft barely got off the ground—measured in mere feet. For 90 years, we've progressed. We started measuring in thousands of feet. As technology takes us further out to where we measure the distances in miles, we increase our capabilities to perform the basic functions of the Air Force. Space is a natural frontier for us. We must go there.

Q: Can we make the transitions that you and I have been discussing on an evolutionary basis? Or are we going to have to spend a great deal of money on R&D to carry us further along?

A: The technology we're using today has taken us to the edge of its capabilities, I believe. We need new R&D. We need the capability to see what is beyond today. What opportunities are there. Technology is going to be our friend for a long time.

Q: Okay. What do you think the Air Force will look like 50 years from today, and what do you think we'll call it?

A: It's very tempting to look out into the future 50 years and to imagine a Star Fleet. But the primary difference between that Star Fleet and the United States Air Force is not the Enterprise. The difference is the threat. As long as our threat is an earthly threat that doesn't come from beyond the stars, what we have is an Air Force that continues to evolve to solve today's problems and tomorrow's problems with tomorrow's technologies.

Q: With the character of the technology we're talking about and the thrust of the discussions about non-lethal weaponry, there comes a philosophical question, and I suppose it has more to do with society than with the Air Force, but what do you see it as becoming? Star Wars or Star Trek?

A: The future of warfare, if you try to contrast it between something like Star Trek or Star Wars, I would have to lean a little bit in the middle ground, actually, on this. Janet and Chris Morris have an excellent concept called "weapons of mass protection." Non-lethal technologies will allow us to achieve the objectives of war without some of the attendant risk.

Q: What are possibilities for non-lethal weapons?

A: Non-lethal weapons perhaps represent the greatest advance in the history of mankind. War has always been a political animal. The purpose of killing was to achieve an objective. If you can achieve that objective through non-lethal means, you have made a great leap.

What's possible in non-lethal technologies? The sky is the limit. We have technologies that are working on destroying rubber products, making roads impassable, shutting down communications, stopping armies in their tracks, destroying enemy information systems. All of these are non-lethal means to an end—to convince the enemy leadership that what they're doing is wrong, and to reconsider.

Q: If you use that kind of technology, haven't psychologically you done more to the enemy than you would if you simply kill him?

A: For nearly 10,000 years, war has meant killing people and attacking armies. You didn't do that because that was your true intent—you wanted to get to the enemy's center of gravity, his capital, change his mind. If you can change that enemy leader's mind without attacking the army, you save lives in his country and in your own.

Q: At the same time you've made him subject to your will and in a very dramatic way, haven't you?

A: The intensity of hyper-war allows us to make the initial strategic attack with such intensity that it causes the whole enemy system to shut down. Other leaders, other rogue leaders seeing that type of a response to abhorrent actions causes them to pause and reconsider. Perhaps strategic deterrence on the conventional level is finally possible.

Q: What do you think Clausewitz would say about non-lethal weapons.

A: Everybody in today's military was raised on Clausewitz. Clausewitz was a man of his time. He had watched the Napoleonic campaigns, and he understood them probably better than any man of his time. It was beyond his comprehension, I believe, to move his mind to a non-lethal form of warfare.

But yet he was a genius. He understood that war was political in nature. And any way you can achieve political outcomes that are to the betterment of your country is successful warfighting.

Q: My friends at the State Department with whom I lived for a number of years always said that war was a failure of diplomacy. Do you agree with that?

A: Several times in the past 20 years I've heard that war was the failure of diplomacy. War is the failure of mankind—the inability for us to deal with the problems on a real time basis on a one-to-one basis. That's going to continue with us for all time. Diplomacy? Essential. The ability to protect our nation through a warfighting capability is equally as essential.

Dr. Sheila Widnall

Secretary of the Air Force

"New World Vistas"

25 August 1995, Pentagon, Washington, D.C.

Q: Madame Secretary, Alvin Toffler says we're in a transitional period. He calls it the "third wave." It is a chaotic period of adjustment to a new way of doing things—largely fed by information technology, of course. The Air Force as an institution is a part of that wave in a big way. How do you see the future for this institution?

A: Well, I do think we're a part of that future in a big way. I think what you're talking about is the information revolution. I think the Air Force is moving—I don't know if it's chaotically, but certainly making a transition to even an increased use of information. I can't comment on whether that's continuous or discontinuous. But certainly, moving from our fighter platforms and our smart weapons, moving into space with the primary use of space being the capturing and providing information to forms of information, thinking about information in terms of a valued commodity that needs to be managed in a war time environment. I think the Air Force is moving in a continuous way towards having a major part of that as one of its core competencies.

Q: In order to be the "Corps" that Hap Arnold envisioned, the Air Force really has to be a leader in science, doesn't it?

A: Yes, I think the whole history of the Air Force parallels and is a part of the history of the development of science and technology in America. At least in the major fields and disciplines that contribute to the Air Force mission.

Q: How do you feel about that? The military has been a great leader in R&D over the years. It certainly has not been perceived that way by the public. But for a long time, it has been a driver of the technology. Its needs have lifted the society. How do you feel about that?

A: Well, I am sorry if the American public is not totally aware of this. In my own field all I need to look at is the development of the jet engine and the development of the jet transport to understand how the military's need and development of technology has contributed immense value to the civilian world. We think nothing of hopping on a jet plane in San Francisco, flying to Boston for really very little money at this point. It's a very efficient form of transportation. It's very safe. All of this is really made possible by the development of the jet engine and the development of the large jet transport which were fundamentally military developments.

Q: But military science has been a big feature of this century, hasn't it?

A: Absolutely. Another area, DoD really long ago saw the potential uses of the computer and began investing in microchips and VLSI integration well before the commercial sector.

Now we are entering a transition where the commercial sector in many areas has now outpaced the capabilities of the military because of their drive for efficiency, cost effectiveness, reduced cost, and the absolute explosion of applications in the civilian and commercial sector.

I think the challenge for the military is to take advantage of that. To avoid doing in-house what would be better done in the commercial world to integrate existing commercial products into our system so that we can save the taxpayers money and get a better product. So we have to be fast on our feet in looking at those technologies.

Q: That anticipated my next question, because many members of the Scientific Advisory Board in their New World Vistas report suggest that very thing.

A: Well, I think it may be a mutual urging. It was certainly in the original frame of reference that I gave to the Scientific Advisory Board for New World Vistas. It was quite explicit that one of their tasks was to look at those areas where the commercial world was ahead in some sense of the dedicated military technologies, and to take full advantage of those, and to really identify those areas where we did not need to pursue the leading edge because, in fact, it was being better pursued in the commercial world. That's an explicit part of their charter.

Q: Is there any reason you couldn't use say a commercial airliner? Is there any reason that you couldn't use a commercial communication satellite if those channels could be guarded? Isn't that the intent and the thought?

A: Certainly. That's the intent in terms of a total system. But there are also components that we should use to integrate components into military systems, and to integrate the results of research and development in the commercial world into the military. So I would say yes, we can use the full-up systems, we can use the components, we can use the technology base, and the scientific results. So it happens at different levels that we need to make use of the commercial products.

Q: It really is a circular system, though, isn't it? You're an engineer. One of the things we did in producing parts of this program were to go to Boeing and look at the way they built the 777, which was off computer production, which the military had done before, in part, and now here is an aircraft that may be useful to the military. It is self-feeding, isn't it?

A: It is. It is, and I think, again, the whole history of my profession, aeronautical engineering, is one of continual recycling of advances through the military, through the commercial, and a continual synergism between those two worlds.

Q: But we are at a change point, aren't we? This is probably, and my memory of this goes back to the end of World War II, this is probably the first time where the military has felt that it could look at the commercial world, and the commercial world was not taking from the military. The 747 was a solely produced aircraft without military support. And then that went the other direction. So we're at an interesting if not chaotic point.

A: I think the situation is even more interesting in the satellite communication area, because there are some revolutionary technologies in satellite communication, and I think one can see without too much stretch how we can make direct use of those—either by simply putting up such satellites, by renting space, time, channels on existing or planned systems, which would fully meet our needs.

Q: This idea of forecasting is a legacy. How does a person like yourself go about implementing it and making sure that this institution is aware of it and uses the finer points?

A: Well, I do believe it is a legacy. I'm not unmindful of the fact that this is the 50th Anniversary of the founding of the Scientific Advisory Board by Hap Arnold and Dr. von Kármán—two remarkable individuals with a remarkable synergism between them in terms of outlook and mission, personality, and their obvious respect and friendship really comes through in all the documents that I've seen.

So I'm certainly aware that it's a particularly interesting, historical time. If you couple that together with this transition that we spoke of, it's sort of redefined the challenges. We can't just progress forward doing a little better at the same mindset we have in the past. I think we have reached a transition. That's why I'm really looking forward to the outcome of the New World Vistas study, because I think it is a discontinuity, a change in direction, and what we will do with the product, of course, is to examine how our current research and development programs can benefit from the insights that the SAB brings, and we're very anxious to get on with that process.

Q: Is there a mindset you now have, after Arnold's setup of the Scientific Advisory Board and Kármán's recommendations, you now have for the first time in the military an officer corps of scientists.

A: Yes.

Q: How will that expand? Are Air Force scientists really able to exert a leadership role now, and how will that expand in the future?

A: I guess I'm not sure I'd use the word expand. We do have an officer corps of competent scientists, yet at the same time we don't want to draw inward. We don't want to do everything in government laboratories. We spoke earlier about the need to maintain contact with the commercial world. So what that really means is developing a unique kind of individual who can not only use, develop and use their own expertise in science and technology, but have both the mindset and the motivation to make some substantial contacts with the outside world, with the university world, the commercial world, with other government laboratories.

So I think the challenge for us is not to do everything inside the Air Force, but to really look through the windows and make sure that we're not becoming isolated in the science and technology area.

Q: Make it a little more corporate?

A: Yes.

Q: Would Kármán and Arnold, if they looked around today and came into this office, feel about what they see 50 years later?

A: I don't know, I think what has happened this year is very telling for the advance of science and technology. As I just reflect on what has happened in say the last six months, we have made a fundamental commitment to the airborne laser program. That has got to be seen as a leading edge capability. We have stood up a squadron of four UAVs. We have awarded a contract for the development of the next generation UAV. We are operating UAVs in Bosnia. And in the information sphere, we're gaining more and more experience with space communications. We are linking space communications. Now you go from the platforms, to satellites, to a ground station, to Washington, to the field. You link, you process, you feed the information back to the platform. So we're doing revolutionary things.

Q: It's already a space force, isn't it?

A: In many respects it already is a space force. We're developing a new expendable launch vehicle. We are putting up a new space-based infrared satellite system. So in terms of just the technological accomplishments of the last six months, I think that the lesson learned from Kármán and Arnold about the importance of science and technology of the Air Force has been reinforced.

Q: What do you see it 20, 30 years from today?

A: Well, I'm not sure I'm in a position to really predict the future. But I think these systems, if you look at the systems we're developing, I think you can see us making the transition from the manned to the unmanned to a much more complex use of information and space information and intelligence. So I think that's where we're headed.

Q: Are you comfortable with it all?

A: Of course. You have to be comfortable with the future, because you have no choice.

General Ronald R. Fogleman

Chief of Staff, USAF

"New World Vistas"

14 September 1995, Pentagon, Washington, D.C.

Q: General, what is the future of this institution? It has grown scientifically since the end of World War II because of Theodore Von Kármán and Hap Arnold, and there seems to be no end in sight. The technology continues to roll. What do you see this Air Force looking ahead 30 years from today?

A: Well, that's a good question. I wish I had a good, concise vision of that. In fact I've got a special group at work trying to help us with that vision, looking back to the experience of Arnold and Kármán.

The fact of the matter is, the United States of America is an aerospace nation. So I think that our Air Force will, in many ways, reflect the interests and the needs of the nation. We exist for one reason, and one reason alone, and that's to fight and win America's wars when called upon to do so. In peacetime, we play a very important role because of our ability to span the globe within a very short period of time. Day to day, we're out there expanding U.S. influence by our presence, our ability to come to the aid of allies, and providing humanitarian assistance as well as other missions.

Q: From a global sense, the intelligence gear that's now being constructed, the access from space, makes this Air Force, although it can be localized on this continent, a worldwide force, doesn't it?

A: It certainly does. In fact one of the most important roles that we play is to provide worldwide situation awareness. First, for the national command authorities. In an environment like we're moving into where the bulk of our military forces are going to be based in the continental United States, there's a great need for our national command authorities to understand what's going on around the world. The sensor systems that we have in space, the various satellites with all their capabilities, provide a presence around the world that allows us to stay wired in.

At the same time, once a troubled spot begins to emerge and one of the regional commanders and chiefs needs support, they normally will call on one of our air breathing assets such as AWACS or our Rivet Joint aircraft that go out there and monitor electronic signals and voice communications, to provide them local, enhanced situation awareness.

So certainly we play a big role in this global awareness.

Q: You sit in the seat that Hap Arnold occupied during World War II. How have things changed for the man in that seat now, since that period of time? Do you still see the same problems? Do you still agree with his vision for this institution?

A: I would say that the situation is somewhat different today than it was at the end of the Second World War. However, the vision is one that is enduring.

The differences focus on the fact that at the end of the Second World War, we hadn't yet clearly defined Communism and the Soviet Union as a threat, but certainly on the watch of General Arnold's successor, General "Tooey" Spaatz, that came into focus. Being able to focus on a given threat and an enemy had great value. I think it was because of the uncertainty that existed on Arnold's watch that he did, in fact, turn to Dr. von Kármán and ask for the *Toward New Horizons* study. He clearly recognized that airpower had come into its own during the Second World War. It was a force to be reckoned with in the post World War II period. Arnold had great experience from his World War I efforts at trying to mobilize and produce aircraft for the Western front. That made him uniquely qualified to take those challenges on in the Second World War. He was a man who understood that technology has to go through a certain maturing process before it can, in fact, become combat power. He wanted to make sure that he could look full sweep at what was on the horizon with technology, and then through a great deliberative process, be able to focus on those things that were most promising.

So given that situation, today mine is one in which I have a much less clearly defined threat, but nonetheless, we live in a world that is recognized as being global in nature. Once again, Air Force airpower finds itself in great demand and we have a requirement to continue to push forward and look for ways that emerging technology might help us support national interests.

Q: Yes, your beat is enlarged over Arnold's considerably. You literally have the world to be concerned about in a very different way, particularly since the threat may come from much smaller forces than he had to contend with. So the character, the nature of the job has changed, hasn't it?

A: I think in many respects it has. The Air Force of the future I think will be much smaller than the Air Force that Arnold knew or that Arnold's successors knew. However, the key is that with that smaller Air Force, to be able to continue to provide the nation the ability to influence events around the world, the only way we're going to do that is by continually exploiting technology and getting more capability as we go forward.

Q: Within bounds of security, how large is this Air Force? How many airplanes does it have? How many personnel?

A: We have a total force Air Force of about 800,000 people. That's slightly over 400,000 active duty men and women. We have about 200,000 Guardsmen and Reservists, and about 200,000 civilians who work throughout our laboratories, our depots, and our major air commands. So you have an Air Force of roughly 800,000 people.

With an Air Force of that size, we're talking about 6,000 aircraft. When you start to look at that, they're divided between all the mission areas, training aircraft, fighters, bombers, airlift, the tanker aircraft.

Q: Compared to Arnold's World War II Air Force?

A: It's much smaller. A much smaller Air Force. The amazing thing is it's got much greater combat capability than Arnold's Air Force had.

I think it's interesting to look back at just one slice, targeting. In Arnold's day, if we wanted to take out a rail yard, we would send an armada of aircraft to attack that whole rail complex, because the intelligence was such that maybe we had a photograph of it or we knew of its existence, but in terms of aim points, what we were interested in doing was saturating the entire target with bombs that were not very accurate, so you had to send hundreds of aircraft to try and achieve some level of destruction.

Today, because of overhead systems that we have, greater intelligence, we're able to determine what the key parts of that rail yard may be. We may not want to destroy the whole rail yard. If we know, for instance, that a building in one area happens to be the switching key we can now identify that and go there and, with precision weapons put a bomb into that building and destroy the switching network.

If there are two or three impact points in the rail yard, a B-2 bomber that has capability to independently target multiple aim points on one pass could do the job. It's a tremendous change in the whole targeting philosophy.

Q: It's a policy question, but maybe you can address it in some way. You have X number of B-2s on order, ready to show up, and Congress wants to give you more, yet you say you don't need that many. Is it because of the effectiveness of the weapon, or what?

A: There's a combination of things. First of all, I would love to have more B-2s, because it is a tremendously effective weapon, and it's a weapon that in the future is going to save lots of lives for the United States of America. I'm convinced of that.

The problem that we have is one of national priorities and defense funding. The funding just doesn't exist today and I can't see anybody who will forecast the funding that will be available that would allow us to buy more B-2s and still have a balanced Air Force. The importance is balance.

You asked me about the number of aircraft we have. That's an important dimension of our Air Force, but unlike Arnold's day, that's not my only measure of merit. We have missile systems sitting alert, we have satellites on station. So now we have a requirement to balance this Air Force as we move forward.

Q: I'm curious. Are you glad to get the SR-71 back?

A: Personally I think the SR-71 is a system that has seen its day. This is the struggle we have. It's one of the challenges of the institution to give something up when newer technology comes along that replaces it. Here's a case of a system that was well ahead of its time, gave us tremendous capabilities with an air breathing asset, and now because of a combination of capabilities—both from space, the satellite overhead systems, and the emerging unmanned aerial reconnaissance vehicle technology—we can do that mission much cheaper with other systems.

Q: And for a longer period of time with the orbit capability of the UAVs?

A: Precisely.

Q: Well, doesn't that bring us down to the point of this whole exercise when we're talking about this program. The size of this force is funneling down, its technology is funneling down to smaller but more capable equipment, to the point where one of these days about everything that needs to be done can be done from a control room here in the Pentagon.

A: Well, I cannot argue that this might be the ultimate outcome. However, I think that's many years into the future. But certainly that's a challenge that we have.

You asked me early on what I thought the Air Force would look like in 20 or 25 years. I've got this group studying this issue. I've asked them to not start today and incrementally move forward. I've asked them to try and imagine themselves in the year 2025 on a low earth orbit satellite looking down at the world and seeing how it has changed as a result of things like the tremendous increases in computing power, the global nature of communications and all of these things. As you look down, determine what capabilities our Air Force ought to have in the year 2025 to support our national objectives?

Then once you have made that evaluation, I want you to reach back to where we're at today...The challenge, then, will be when to start divesting myself of these systems, and start pumping more money into a promising technology that has come along that will lead me to the point where I can do this mission better, with fewer people in the future.

Q: You're going into space. There's no question about that. Does that add to the size of the Air Force, or does it even cut it down further?

A: I think there's a balancing act that occurs as a result of that. We earlier discussed the SR-71. Here's a case where in terms of force structure on the ramp, it's been diminished. It has been replaced by satellites on orbit. Those satellites on orbit must be controlled by our space forces out of mission control centers. So to the public, there's less, there are fewer air bases, there's less visibility. On the other hand, we've built up in less visible areas.

In the aggregate, I think we will get smaller as a result of this, because we will be able to do more things in a more flexible fashion.

Q: You're a devoted airplane driver. What's the future of the human in the cockpit?

A: Well, I think we're going to have humans in the cockpit for a long time to come. However, I think it's conceivable that as we go into almost the next generation airplane—particularly as we look at something like the JAST as an F-16 replacement, that's an airplane that we will buy over a long period of time, probably 15 or 20 years. The early versions of that aircraft I think will be manned. But by the end of that buy, we may very well be buying some of those aircraft in an unmanned configuration.

Q: And they'll be more capable for it, won't they?

A: Well, they'll have some advantages that the manned aircraft won't have. They'll have some disadvantages. But certainly one of the reasons that we're looking at unmanned aerial vehicles for reconnaissance is that you want to send these things into hostile environments where you don't have to go through the agony of mounting a rescue effort if the vehicle gets shot down. So we're examining these kinds of considerations. And in turn, I don't need as large a rescue force. So it's all connected in terms of impact of advances in one area versus another.

Q: What do you think Hap Arnold and Theodore Von Kármán would think if they could see where you are today?

A: Well, I don't know what they would think, but I would hope that they would feel that they had brought forth a great military force; that we had achieved the promise and potential that they saw. That Kármán himself would see what a tremendous contribution he made not only to our Air Force but to the nation by bringing together this group of outstanding scientists, and giving to the Air Force a blueprint for how to move forward and become what we are clearly today, the world's most respected Air Force.

Q: If you, in the same chair, could look 30 years into the future, how would you feel? Would you feel like a grandfather, a proud grandfather? How would you feel?

A: Well, I would hope that I could feel like a proud grandfather. I would like to feel that today we have a unique opportunity in our country. Because there is, for the first time in many years, no day to day threat to the survival of this nation. We have the opportunity to step back and reorient some of our defense priorities and our national priorities. I would hope that on my watch, within the Air Force we can be open minded enough to seize the opportunities that are coming, that we'll be able to pick out those one or two technologies that will leverage us into the future. We see some of that starting to emerge.

Q: It's fun, isn't it?

A: It's exciting.

Dr. Gene H. McCall

Chairman, Air Force Scientific Advisory Board

"New World Vistas"

13 July 1995, The Beckman Center, CA

Q: Dr. McCall, first of all, would you give us a rundown of the mandate this Board has for this particular study?

A: This study commemorates the 50th Anniversary of the Scientific Advisory Board. We were asked by the Secretary of the Air Force and the Chief of Staff of the Air Force to project Air Force technology and technological capabilities into the 21st Century. Our charge was to look out a decade, or even more than a decade, and in fact we're probably extending the study to three decades, to determine the effect on the Air Force and its capabilities of the new technologies that are emerging in the world today. But as you realize, technologies don't stand alone. For one thing, one has to pay for technologies. The commercial world is developing some technologies faster than ever before. The military is not the driving force behind technology such as information, computers, even aircraft in many cases have shifted to the civilian side. We also see space capability shifting to the civilian side with new space communication systems and space surveillance systems.

The world is changing so rapidly, the Secretary and the Chief asked us to try to make some sense out of it for the Air Force. That's what we're about.

Q: With the private or civilian world carrying its own momentum in development of science and technology where, as we all know after World War II and for a period of quite a long time, the military did drive a lot of development. But now that that pendulum has swung, what's the Air Force to do? I heard some comments at the Westfield session that said, "Hey, commercial is going ahead without us, and we're not using technology until it's fully developed, which means we in the Air Force are using 20 year old technology." Does that stand up?

A: No, it's got to change. One of the advantages of being in the commercial world is that one can use state of the art, up to date technology today. Part of the reason we can't do that is we simply can't procure systems in the way that the commercial world does. That has to change.

The other thing that has to change is that we can no longer be dedicated to keeping a system forever. We have to understand that things wear out—not because they're no longer shiny. They're still shiny in a couple of years, but they just don't work well any more. They don't fit with the rest of the world. So we've got to learn the lesson of the commercial world in terms of procurement and use of state of the art technologies, but we've got to use those technologies in a uniquely military way.

Q: I guess one of the most beautiful examples of using something until it's completely obsolete in all its ways is the B-52.

A: Well, yes, that's true. Although aircraft technology has not come along as fast as you might think. We've had military developments such as stealth, low observable aircraft, smart bombs, things such as that. We have not yet gotten rid of the need for a heavy weapon hauler. So in that sense, the B-52 is still applicable. That's why it's staying around.

The Boeing-777 will not replace it, nor will the B-2 in fact. Together, we're trying to put all of these systems together to build a true weapon system for the United States, a complete Air Force, a complete system of airpower.

Q: You brought up the "triple seven." What does it offer in terms of state of the art to the Air Force?

A: One of the things the "triple seven" offers is a way of building airplanes. It offers automated designs. It has automated flight control systems that have principles which will be very useful to Air Force airplanes in the future. It's just a different way of thinking about the way one develops airplanes. Independent of the capabilities, I think the airplane has some capabilities that the Air Force needs, such as large hauling capabilities. But in many ways, in the use of commercial technologies, we're thinking of societal changes in the Air Force as much as we are improvements in the technology.

Q: The way we think about the technology?

A: The way we think about developing things, the way we think about using technology, the way we think about getting rid of old systems. You mentioned the B-52. However, I think the best example is probably the KC-135, which is the old Boeing 707. Under current plans at retirement age, the average age of the fleet will be 79 years. Most of us would be a little nervous about flying a 79 year old airplane, especially since the outlyers are going to be nearer 100 than they are 80. I don't know if that's going to happen. Presumably these airplanes are completely rebuilt by then, but certainly it's not the way the commercial world thinks about airplanes.

Q: So what happens next? In the finished report, what are you going to tell the Secretary and the Chief about this? I think you've probably summarized it pretty well, but can you give me a summary statement?

A: I think what we're going to tell the Secretary and the Chief is that the structure of weapon systems, independent of the technologies used, are not going to be those of the past. They're simply not. We are very likely to have pilots sitting in the United States rather than in their airplanes — not because it makes the pilot safe, necessarily, but simply because it's a more efficient way of completing the mission.

We are not trying to sell the Air Force on change for its own sake. Nobody is interested in that, because it's been a very successful organization. But I think what we are saying is that the

demands of technology will force changes in the structure, will force changes in the way we think about weapon systems, and that ultimately will force changes in the way that we think about organizations and applications of technology.

The specific items that I see at the moment are going to be applications in space, applications of unpiloted airplanes, new munitions that have greater destructive power, and overlying all of it, information systems that connect them all together into an integrated whole. There are not going to be these individual, autonomous units out there striking targets. They're going to be tied together with an information system; they're going to be directed on a moment's notice from one target to another; and that is going to change the way we think about airpower forever.

Q: Don't you also need, if going into space, looking at the 30 year reach, don't you need quick lift and some quick, fast turn-around for lift to space? You don't have that now.

A: That's true. The civil world is trying to develop that, and I think that's one of the areas where the military will follow the civilian developments. We will have fewer demands for launches, I think, than the civilian world with all of the communication and observation satellites they're going to be launching. I think we'll have to look to them to solve the problem of efficient space launch.

Q: Is there any problem, any reason the Air Force shouldn't buy civilian services?

A: The answer is yes. There is "a" reason. That is that the Air Force needs services in wartime. Now what that means is that you need services that cannot be interrupted by terrorists or interrupted by your adversary attacking launch bases or vehicle production factories or whatever. But once you provide that protection, there's no reason that the basic principles can't be used. There's no reason that we can't provide a small military reserve with most of our functions in the civilian world.

Q: So once again, a summary statement, what do you think, based on your talk with your colleagues here and your own ruminations at night, what do you think the Air Force will look like 30, 50 years from now?

A: I think the Air Force will have airplanes with pilots in them. I don't think there's any doubt about that.

There is no way that a computer is going to be as smart as a human being in 30 years. It's not going to happen. That will probably be a small fraction of the airplanes in the Air Force, on the other hand. I think the Air Force will consist of planes that have no pilots in them, have pilots still—a human brain flying the airplane. I think we'll see those people back in perhaps the continental United States. Sometimes I say with information systems that in a theater of operations the highest ranking officer should probably be a major. That everyone else can perform better if they're back at a central location. It may not be a very popular point of view, but I think it's going to happen. I think we're going to see much smarter weapons, direct communication between weapons and the people who are flying them back in the continental United States.

I think we're going to see each person in the Air Force responsible for more of the mission of the Air Force, because all these people will be connected. They can get help from others, and by making available the information and the aid that each person needs, that person can be given more authority and more power. So I think we're going to see a smaller Air Force with more competent people—more competent in terms of exercising the new technologies, and people with more authority at lower levels.

Q: As a footnote to that, don't geopolitical realities make it necessary to have an Air Force that's almost totally launchable and returnable to the United States?

A: It does at the moment. I don't know what's going to happen in another 10 to 30 years. That was not the case ten years ago, so maybe it will not be the case in another ten years.

I think we are developing the capability for doing that—for launching and recovering to the United States, and because there's a strong possibility it can happen, I think we're going to have to develop those capabilities.

Q: And we're going to have to consider a much wider envelope. That is, an envelope that extends into space, aren't we?

A: Yes, an envelope that extends into space, but also we're going to have to think about doing things differently. We have to extend the envelope into space. We have to, rather than being distributed worldwide, we're going to be distributed, perhaps, only in the United States, and operate worldwide. It's quite different.

But we're also going to have to think about an Air Force in terms of what it's capable of generically, because we don't know who the enemy is at the moment. We have different enemies that will come and go, at least over the next few decades, I believe. So rather than thinking of striking a particular target in the Soviet Union against a particular defensive system, and designing a mission and a weapon system to do that, we're going to have to think in terms of capabilities—such as striking particular classes of targets, such as operating at particular distances rather than on particular spots on the earth. That's a completely different way of thinking about the projection of power.

We're going to have to have systems—mostly in space—which provide us with a world view at all times. We don't really have that at the moment. And when I say provide us, I mean provide these people at the lower levels who were empowered with not just a system which provides the President or the Chief of Staff, the Secretary with information about adversaries, but which provides real time information to the people who really have to deal with it.

Q: Access?

A: It's access that's going to change, yes.

Q: What about peacetime or non-military applications of military might in the future as a possibility.

A: One of the things we haven't covered in this conversation is the question of what the Air Force does in peacetime. Right now the Air Mobility Command is engaged in humanitarian commission, humanitarian missions around the world. The Air Combat Command is engaged in establishing no-fly zones in Bosnia and Iraq, patrolling these zones. That sort of mission will continue. But I think the humanitarian aspect of peacetime operations will become more intense—perhaps not so much in these revolutionary wars or civil wars in countries, but just because there are going to be natural disasters, there are going to be famines, and I think we're going to respond. I think we're going to continue to respond the way we are.

The Mobility Command will be flying into every country in the world. We'll have to do that under adverse conditions, all weather, day/night operations, and we're going to have to provide them with the technology for doing that. It doesn't exist at the moment. There should be a strong technological development component which is associated with moving people and things from one place, say in the United States, to anywhere else in the world. We don't have that today, but I think that's going to be a big part of the peacetime operation in the future.

Q: Is the C-17 part of the answer as the carrying mule for that?

A: The C-17 is part of the answer in that, earlier I mentioned that in space launch we need to have a military component for special cases and special times. The C-17 is a military transport airplane. It can fly into places and under conditions that one simply cannot fly a civilian freighter. So I think in that sense, yes. It will be a very useful adjunct to the civil fleet in the future.

Q: I think in essence the question is, how does this report carry its own weight through the next couple of generations, and how does it get taken seriously and not just put on a shelf and collect dust?

A: We've approached it from really three different aspects. The first is that in the next decade, we have to have technologies that are defined today at pretty much the demonstration phase. If you want to get something into the force in ten years, you have to start with something which is pretty well defined right now. In 20 years, one can discuss the use of technologies that are currently in universities, perhaps pretty well established as university research fields, and in 30 years, fields that are just beginning in the universities. That's the way we separated the three decades for applicability of the study.

The other thing that one has to do is to define the actions the Air Force has to take tomorrow to reach the technological end points that we're specifying. It's really important because otherwise if you tell someone here's what you can have in 30 years, they'll say, "Thank you very much. Twenty-eight years from now I'll start to work your problem." That's not what we mean.

It means that we start tomorrow to develop the technologies that are going to be available 10, 20, 30 years from now.

The document itself should be written in a way that it provides some guidance for the next three or four generations of leaders. I hope we can write it in a way that even as it becomes

obsolete in terms of the technologies it promotes, and it will do that fairly fast, the spirit of it and the sense of developing technologies for the future will continue to be useful for the Air Force.

Q: Excellent. How about the inertia factor, though? Do you feel the Air Force is capable of doing it that fast?

A: I think so, yes.

The Air Force is really a very flexible organization in some ways, and that is that as with any large organization you tend to have people at the top who are visionaries, and you have people at the bottom who are ready to go out and do things. If these two communicate on the same wave length about the same problems and agree, then things happen very rapidly.

Dr. Edward A. Feigenbaum

Air Force Chief Scientist

"New World Vistas"

1 September 1995, Pentagon, Washington, D.C.

Q: Dr. Feigenbaum, we're at an interesting point in history. I was talking to Alvin Toffler the other day, and he was talking about a civilizational upheaval largely fed by the computer and other technologies that are advancing so quickly. How do you look at it in terms of the Air Force? Do you feel that the Air Force is ahead or behind at this point?

A: I see the same waves that Dr.Toffler describes as occurring in the Air Force. That is, we are moving out of our second wave of high tech machines into our age of information. The Chief of Staff of the Air Force has called that the fifth dimension of warfare—beyond air and space.

The commercial sector leads the military in information technology. It's a very strong commercial driver. We have the high volume production of chips, the high volume production of software, and other services and aspects of the information revolution. These are being well developed in the commercial sector. The challenge for the Air Force is to integrate these great and wonderful developments in the commercial sector into useful Air Force systems.

The problem for us is two-fold. One is that the same wonderful systems that we can buy from the commercial sector, our potential enemies can also buy from the commercial sector. The other is that the commercial sector will not necessarily produce all of the things that we need. There are some Air Force-specific things. Software, for example, tends to be, as you move toward the system level, quite specific. Software is a technology of details. These are Air Force details. So we're going to have to focus on Air Force specific architectures for software systems.

Q: There are some things you don't want to share with other people, and you do need specific systems, don't you?

A: A good example of a specific kind of system occurs from the end of a fiber, a communications fiber, to a mobile aircraft, mobile platform.

We're projecting in our report essentially infinite band width for use on land masses that are connected by fiber. Of course it's not actually infinite, but from the Air Force's point of view, it's effectively infinite.

When you get to the end of the fiber and have to get to the mobile platform, like an aircraft, then the band width constricts severely. Commercial industry is not going to solve that problem for us. That's a problem from end of fiber to airplane, and we have to work on that problem.

Q: You do have an officer corps of scientists in the Air Force which to me seems unique. Is there a way in the Air Force labs to dedicate to that kind of specifics and to be that elaborate?

A: The Air Force laboratories are primarily laboratories which offer technological guidance to the process of buying technology from industrial firms. We specify what we need, we get requirements. Our laboratories help the SPOs to purchase technology carefully and wisely.

Q: In other words, point a contractor in a specific direction and say this is what we need, now tailor-make it.

A: In addition to that, the laboratories help the SPOs with technical guidance. What's feasible, what's not feasible, when are things going off the track.

Q: What do you see, what capabilities do you see coming down that excite you in the next 20 to 30 years?

A: I think if you go back to your first question, the question having to do with Toffler and the third wave and the information revolution, I think you have to keep your eye on that ball. That's the critical thing to keep your eye on—the information revolution.

In the building here, in the Pentagon, Dr. Andy Marshall and others have talked about the revolution in military affairs, but that revolution is fueled primarily by an information revolution.

Why is that? When we look at the technologies we're accustomed to—let's call them second wave technologies, to use Toffler's terminology—they change slowly over time. For example, a change of 30 percent in cost effectiveness, that is power per dollar from an engine, is considered to be a very significant change by engine technology people. The power of computers is doubling approximately every 20 months. That is, for the same dollar, you get twice as much computer power every 20 months.

Typically, a scientist thinks of a revolution in a technical sense as occurring when you have what a scientist calls an order of magnitude change which translates into a factor of ten. For example, you drove here today. Had you walked, you would have been traveling an order of magnitude slower than cars. That's one order of magnitude—walking and driving.

During the development of computers, computers have changed their cost effectiveness by six orders of magnitude—by a factor of a million. That compares with things like the 30 percent number that I was using before. We're doubling the capability-bang for the buck-every 20 months in computer power, in the size of memory for computers, and in the cost of communications, which is falling.

Q: That makes the possibilities very hard to decipher, or very hard to predict, doesn't it?

A: The challenge for the Air Force and for all of us in the society is to envision how we will use this extraordinarily cheap information processing power. It's effectively zero cost. It's not really zero cost, but the chips and the communication, the carrying of bits is so cheap that we can conceive of it as being essentially zero. What are we going to use it for? What are we going to do with it? Are we going to do human language understanding? That is English language

understanding? Are we going to do speech understanding? What kind of intelligent agents will we have working for us? How will we apply artificial intelligence to the task of helping us search, helping us do our daily work, helping us solve complex problems like logistical planning and so on.

The key challenge is, we're going to have a surplus of information processing capability that we need to use intelligently and wisely.

Q: But going back to your earlier point, the other guy has that capability, too. He can go to Radio Shack or IBM and buy it off the shelf. How do we protect against that? Do we just have to be smarter and faster?

A: I think that's the answer. We have to innovate rapidly.

It is true that the same low cost computing power, communication capability, is available to our potential adversaries, but the use of those in highly effective ways will be based on the creativity of our industry and our military technologists.

Q: It's also widespread redundancy and the use of multiple sources of information, isn't it, rather than the single source that makes your bench deeper, makes you more effective?

A: We have a rich variety of data sources not only all over the Air Force, but all over the world. To use this overworked term, paradigm, the right paradigm for which to think about the future is the paradigm of the World Wide Web or the Internet, with millions of smallish pieces of knowledge and information connected together, easily accessible by anyone from any work station.

Q: And it's the guy that uses that the most effectively who is the top dog.

A: We hope.

Q: All right, if you'll look at this in the long term, what do you see... You see the amazing things that are going on, probably have a better overview of all of this than any of the rest of us. Where do you see it leading? What kind of an Air Force will we have in 30 years from now?

A: I see one of the important directions for the Air Force, technologically speaking, is to move in the direction of using this enormous computer power for unmanned or uninhabited aerial vehicles. Since computers and their software are getting more and more capable, and our sensors and instrumentation are getting more and more capable, we have the ability to direct warfare without exposing our pilots to danger. That's one of the important directions.

Another important direction is the continued evolution of precision strike which was enabled by information sources and computers.

The Air Force will also be focusing on what the Air Force calls situational awareness. That is, trying to understand from the myriad sources of information and data flowing in from the

sensors to the command centers, trying to use automatic methods for creating situational understanding of what is actually happening out there.

There's a paradox. Our pilots say that they would, on the one hand, like as much information as we could pump into them. On the other hand, they don't want too much because they're very busy.

Q: Just tell me what I need to know.

A: Just tell me what's important. Tell me what's right. So that we need to have effective information fusion, situational awareness. And since we have these billions of cycles per second, we only need the techniques now, the software techniques, to generate correct situational awareness.

Q: Does that auger for a smaller Air Force as a unit, although a technologically more capable one?

A: I think as far as the size of the Air Force goes, the Air Force has taken tremendous reductions in size and I doubt whether it will become even smaller than it is today. The current leadership, I think, feels we are at the bone. There is no more fat, no more muscle. We are at the bone. So I think we will use our technology to augment the capability of the relatively few people we have left.

Q: Is space important in the information-gathering spectrum?

A: Space-based resources for gathering information are vital to the country as we know from our various national sources, and they're vital to the Air Force.

Q: Is there any future in using commercial space-based resources for Air Force purposes?

A: The Air Force believes that it needs to exploit commercial developments in space as in other places as much as possible. So, for example, a great deal of military communications will be going through space-based communications purchased from commercial vendors. When high speed data networks are launched in space, for example from Iridium or Teledesic, the Air Force and the DoD will be major customers of those networks.

Q: Is that a switch around? I can remember at a time when I first came to Washington in 1969 where it was accepted that the military research drove commercial technology. Has that reversed itself?

A: Not in all areas, but in the information technologies, certainly that has happened. The DoD and the Air Force do not have a large enough need to significantly affect the commercial sector, so that we are basically purchasers of commercial technology, except in certain critical situations where we need to have our own.

Dr. Richard P. Hallion

Air Force Historian

"New World Vistas"

28 August 1995, Bolling AFB, D.C.

Q: Dr. Hallion, that period right before D-Day when Hap Arnold began to bring together his scientists' invasion, was critical to the future of the Air Force, wasn't it?

A: It certainly was. It was an outgrowth of a number of factors that influenced American aviation even back into the interwar years, from the First World War to the Second World War. We had been very concerned at the beginning of the 1920s about the relative lack of scientific excellence in our aeronautical engineering establishment. A private fund, the Daniel Guggenheim Fund for the Promotion of Aeronautics, radically transformed American aviation. They set up schools of aeronautical engineering around the country, sponsored flight testing and the development of actual flight technology hardware. On top of that, they brought the most distinguished scientist of his generation to the United States, Theodore von Kármán.

Now Theodore von Kármán, by his presence and his force and creative genius, really transformed the way aeronautical engineering and aeronautical engineering education was undertaken in this country. It was Hap Arnold's direct experience in 1940 and 1941 when he was studying what was happening in the war in Europe, and particularly the potentialities of turbo jet propulsion, that really led to the creation, ultimately, of the Scientific Advisory Board. Of course in 1941, when he made his great survey trip to England and met with his opposite numbers, he was exposed there to the technology of the jet engine. That so shocked him to think that the United States had missed out on that potentiality, that he determined never again to let the United States find itself in that position. In order to prevent that, he felt that the Army Air Forces—later, of course, the basis for the United States Air Force today—he felt the Army Air Forces had to have its own inherent scientific analysis capability, if you will.

Q: Its officer corps of scientists?

A: Precisely right. But it was more than just that. Both an officer corps and a trained civilian corps, and then the idea that the Army Air Forces would maintain outreach to the academic world, to the larger scientific community, and indeed, to scientists in other nations.

Q: Let's take a few steps back. The Guggenheim Foundation. That brought along an era in which people like Wiley Post and Amelia Earhart seemed to thrive. I got the impression in reading that they were doing the best science they could, but they didn't quite know what it was.

A: It's interesting. I think the two principal figures behind the Guggenheim activities—Harry Guggenheim, a World War I aviator; and his father Daniel Guggenheim, a very successful

American entrepreneur who saw the business potentialities in aviation. I think they did have a clear idea of what they wanted to accomplish. They wanted to make aviation practical and safe and of great value to the commercial development of this country. So they sponsored a lot of work on blind flying research. They sponsored a lot of work on airline safety and on safety issues in general. But they realized very quickly, after taking a tour around the world and studying aeronautical engineering and how it was practiced in other countries, they realized very quickly that the Corps was creating a strong aeronautical engineering enterprise in the United States.

Q: And I hear other names like Lindbergh and Doolittle.

A: We tend to think of those people in a romantic, almost a barnstorming way. But in point of fact, Wiley Post's greatest interest, which unfortunately due to his untimely death he was not able to fulfill, his greatest interest in flight was to create an aeronautical research establishment. Amelia Earhart made a number of advances in flight and was very interested in the scientific and technical side of flight, far more than just the record-setting that we associate with her name. That was certainly true, say, of Jimmy Doolittle who was the first Ph.D. in this country awarded on the basis of his scientific conducting of flight testing; and for that matter, Lindbergh. Lindbergh's flight across the North Atlantic, we have often heard the term "Lucky Lindy" or the "Lone Eagle." But there was a great deal of very careful planning that went into that flight. That reflected the climate of the time.

Q: So there was a little bit here, a little bit there, but then along came Kármán into Caltech and pulled together a clique of people that started working as a unit, didn't they?

A: There were a series of Guggenheim schools that were founded with Guggenheim money. The Guggenheim money typically went toward establishing a trained professorate at the institution. It went towards purchasing laboratory equipment, creating a wind tunnel, things of this sort. Bringing in key faculty and administrative people. And of the Guggenheim schools, certainly the one that became the crown jewel of the Guggenheim schools was Caltech. The so-called GALCIT. The Guggenheim Aeronautical Laboratory, California Institute of Technology.

What's very interesting is the breadth of interest in aeronautics that took place at Caltech. You know by the end of the 1930s, you had people there that were not only interested in common sense or practical aviation, commercial aviation development, transport development, but you had a number of people there that were looking at cutting edge frontier issues. They were looking at trans-sonic and supersonic aerodynamics. There was a small but very active group that were looking at rockets and the potentiality of rocket propulsion, so really, Caltech very quickly moved to the forefront.

I think because of Kármán's very close personal relationship with Hap Arnold, this resulted in Caltech having a very special interest in the military side of aviation. Certainly Caltech's work in World War II was extraordinary.

Q: How did that relationship come about?

A: Well, it came about basically because Kármán had met Hap Arnold in the early 1930s. The two just became very close friends and they developed a strong social bonding. Hap Arnold was an individual who had a profound interest in the technology of flight. Kármán was "the" major figure in aeronautical engineering education in the United States at that time. There was this natural drawing together of the two.

Q: So Operation LUSTY. D-Day. You've got PhDs trudging into Europe in the dust of the advancing allied forces and snatching up science as they went along. How productive was that for us?

A: It was very productive. However, I think one thing we have to keep in mind is that very often what we uncovered in the rubble of Nazi Germany did not transform American aviation. In many cases, it confirmed roads we were already on.

For example, the swept wing. If you take a look at the history of the swept wing, you find that actually American scientists and engineers were already committed to a swept wing future, and the discovery of German swept wing research confirmed for them the choices that they had already undertaken.

But what it did show is the Wellington Syndrome. Wellington said that the Battle of Waterloo was, "a very close run thing." That was very true in terms of the Third Reich. When we saw how the scientific establishment of the Third Reich had served that nation and what Nazi Germany had been able to come up with, I think it reaffirmed this lesson in Arnold's mind that the United States in an atomic era, in a jet era, in a rocket era, could not afford to take second place behind other nations.

Q: So the Scientific Advisory Board?

A: So the Scientific Advisory Board, and indeed, the whole building of a scientific and technological tradition within the Air Force.

Q: Has there ever been any doubt that he was right along the way?

A: No, I don't think so. I think at the time people might have wondered during the drawdown after World War II. I think there were many of the arguments that we hear today in the post Cold War era. Where is the threat? Who are the enemies? The times were very uncertain and we found certainly then as now that enemies will appear, threats will appear. You have to be prepared to counter them. So the wisdom of Arnold's and Kármán's choices in those days I think has been borne out very well.

Q: The parallels are very striking.

A: They're quite striking. There was one major geopolitical difference. There was a strong monolithic bloc that appeared after the Second World War, and that was, of course, the Soviet Bloc, aligned with what became the Warsaw Pact and, of course the Sino-Soviet dimension of that later into the 1950's. But basically, in terms of the radical technological transformations that took place in aeronautics and in astronautics after 1945, they had their own parallels in terms of the rapid development of aviation that had taken place in the 1920s and 1930s.

I think the time compression in this century that we're seeing in aviation and space has been extraordinary. In 1969 when we landed on the moon, the common analogy or the common comparison people made was to the flight of the Wright Brothers in 1903. They said in 66 years we've gone from Kitty Hawk to the moon. In fact, it was closer than that. It was actually from 1926, it was 43 years. It was from the time that Robert Goddard fired his first liquid fueled rocket to the landing on the moon.

And if you take a look at the progression of technology in the aerospace field, we find that it follows this classic biological growth curve. You have slow incremental growth, the rapid maturation of the technology, and then the leveling off as you approach a boundary. Then you go from that point to a paradigm shift into a new era.

We saw this with the development of the all metal monoplane. We saw this with the development of the turbojet engine. After the Second World War, at the time period that Kármán and the Scientific Advisory Board are getting underway, we see it in the area of supersonic and trans-sonic aerodynamics. We see it in the area of rocket propulsion and space flight. Those were all transformations that radically altered the way in which we view air and space power.

When we see the maturation of the airplane in the 1950s, it's truly then that we can start thinking in the terms that we use today—global reach, global power, global presence. Because the roots of all that, the reliable, long range jet propelled airlifter, air refueling, the precision revolution, things like this, we can see the seeds of all of those maturing, and indeed flowering, in some cases, that far back.

Q: It seems to me that the advance has come almost tumble over end since the end of World War II. Alvin Toffler says that we got to the point in the '50s where there were more white collar workers than there were blue collar. Then the advance of television, the jet engine, and the high speed computer. He also includes the birth control pill. Together these have created a civilizational upheaval. It seems to me we are in a chaotic period of development right now that has yet to smooth out, as you said, as the technology matures. How far into that are we, and where are we going?

A: It's fascinating to speculate. If we take a look at the progression of technology, concentrating on the technology side, we find that we have had radical transformations in our technology since the time of the scientific revolution. We had the scientific revolution in the 17th Century, the so-called industrial or technological revolution in the 18th Century. When we think about it, at the beginning of the 19th Century, people rode horseback or they walked to get between destinations. By the middle of that century they were taking steamships or they were taking locomotives. That was a radical transformation in and of itself.

By the turn of the next century, by 1900, they were traveling over intercontinental distances by steamship, and we had the beginnings of the revolution in flight. By 1950, we were seeing flight such a common element of our existence that already by 1950 more people were flying across the United States than were taking trains across it. By 1958, more people were taking planes across the North Atlantic than were progressing across it by ship. So this kind of radical transformation we can relate to in a very clearly understandable way.

What we have a more difficult time relating to are the less obvious transformations, the ones that you mentioned—the communications transformations, knowledge-based transformations, the shifting and the transfer and the utilization of data and information. These kinds of revolutions, when we take a look at the potential they offer to us, we see now only a glimmering of what may be possible to us. In the military sense, certainly today, and the Gulf War clearly showed this, we are so dependent now on not merely what could be seen as traditional air and space methodology, or traditional air and space technological competencies, but we're so involved now in the satellite revolution in the knowledge revolution, in all those elements that make up in the minds of some people the information warfare potentialities, that in the future we're going to see war transformed very greatly from what we see today.

One thing that is very dramatic is that we have gotten very much away from the notions of warfare that governed war at the beginning of the 20th Century. At the beginning of the 20th Century, people did not really speak in terms of mobile conflict. They did not really speak in terms of wars in which you had large scale maneuver over vast distances. They were operating to an older paradigm. Tragically, that older paradigm was responsible for millions of casualties in the First World War.

On July 1, 1916, in the first three hours of the Battle of the Somme, the British Army took 60,000 casualties, and that level of casualties was considered acceptable.

Obviously, we have come to a point in warfare where we simply do not behave that way. The Gulf War clearly showed that increasingly we want our wars to involve as few casualties as possible. Because of this, the next transformation that we're likely to see is very much this transformation into what might be termed bloodless war.

Q: Non-lethal weapons?

A: As much as possible we will emphasize non-lethal weaponry and we will emphasize approaches to conflict that will minimize actual human suffering.

Q: It also seems that now we're into pinpoint targeting, you can very much localize a war and isolate it to exactly the point you want to take out.

A: A very good point. Indeed, what that does is it gives decisionmakers a great deal of flexibility. For example, the Gulf War shows this. In the Gulf War, we were confident, taking precision weapon systems, stealth fighters with laser guided bombs, cruise missiles, into downtown Baghdad, into urban areas, and actually getting these systems to be used against pinpoint targets. We had the confidence that we could do that without causing what was termed collateral damage.

In World War II, air power was much less precise, simply because the weaponry was much less precise.

To put this in some sort of way we can measure it, in World War II, the average distance that a 2,000 pound bomb dropped off the aiming point was 3,200 feet. That was still considered acceptable accuracy. It shows that precision is a relative term—relative to the time in which you're using it.

In the Gulf War, 80 percent of the laser-guided bombs that we dropped in the Gulf War fell within three meters of the aim point. Now that's the transformation that we see in precision. And when you're able to do that, you're able to reduce sortie requirements. You're able to use your military forces much more effectively. You're able to use small military forces. You're able to get much higher leverage out of those military forces. Obviously, that's very, very important.

Q: All of this rapid advance is confined to the global system. Where does the Air Force logically go if it is to expand, or perhaps it isn't to expand? But is space the natural step for the Air Force as a technological unit?

A: I think what we're finding increasingly is that the demarcation that we have always thought between air and space, while it might have significance in areas such as air law and space law, that in point of fact in a military sense, in an operational sense, the demarcation is becoming less and less significant. We need, as a service, to operate in both. Does that mean we need fully fledged manned robust space systems akin to the systems we operate within the atmosphere today? I personally think that at some point we will, indeed, see those evolve. Whether they will be in the short term or the long term will depend upon how we sort out our national needs.

What we do know is that we have to use air and space together effectively. We cannot win with just the one. What we can see very clearly is that there has been a very dramatic shift in the use of military power in the 20th Century. At the beginning of the 20th Century, military power was defined in terms of decisive surface warfare. In the 20th Century, we saw a radical transformation of military power in which it became three dimensional—from under the sea and from above the surface. We found that three dimensional forces hold two dimensional forces hostage. Because of this, without question, it is the air and space weapon today that is the most decisive and the most important weapon that a nation has at its disposal.

This goes back, really, to something that was pointed out in 1945 by a great theorist of war, J.F.C. Fuller. Fuller stated that at any period in military history, you found that the fulcrum of combined tactics, as he termed it, had to be built around the weapon with the greatest reach. In the air power era, he said, that weapon is the airplane. Those words have certainly been found true in the present day.

Q: Where does it go from here? It depends on political/military thinking; it depends on blending that kind of thinking with the technology that's available and the rapidly advancing technology. No one can predict what that technology will look like three years from today, it's advancing so rapidly. What's the Air Force going to be?

A: I think actually we have these visions that people promote of what the future will be. Robotic based futures or whatever.

I would simply say this. The history of technology shows that the range of technology choices that a society is presented with tend to be almost infinite. The development is so explosive and the expansion is so dramatic that even enthusiasts cannot adequately predict where the technology will go.

H.G. Wells, for example, as enthusiastic as he was about flight, did not foresee that by the year 1950 we would have large-scale commercial aircraft service. He thought that it might possibly be available to us by the end of the 20th Century.

Jimmy Doolittle, as profound a prophet of air as he was, himself, was astonished at the tremendous rate of progress we made in space flight. We only know that we will be confronting a rapidly transforming and unfolding future. What we realize, the challenge we realize we have to face is that we have to have the technology options available to us to fulfill whatever the requirements are that we confront at that time. So what that tells us is, no matter what the world situation is, no matter what the domestic situation is, no matter what our funding situations are, we need viable, focused, and strong scientific and technologically oriented research establishments to make whatever future we face possible to us. I think the experience of the Scientific Advisory Board shows us that it plays a very valuable role in our existence up to the present day, and will play a very critical role for us in the future.

Q: So Arnold and Kármán were right.

A: They certainly were.

Q: Do you think they'd be surprised today?

A: I don't think they'd be surprised. I think they'd be surprised, perhaps, at the pace of the science and surprised at the pace of the technology, but I think they'd be very satisfied at what they accomplished.

Natalie Crawford

RAND Corporation
Deputy Director, Project Air Force and Chairperson, *NWV* Attack Panel

"New World Vistas"

13 July 1995, The Beckman Center, CA

Q: You made a presentation at Westfields that I found very compelling. You were talking about the needs for attack in the next 10 to 30 years, based on the technology that we know today. I wonder if you'd review that for me?

A: Certainly. We view the role of the word "attack" as changing in the future. In the past when we thought attack or expressed that word, it's generally been with destruction in mind. With the political environment the way it is today, where we have a need to be able to accomplish an objective—a military objective or military task quickly—we need to be able to do it decisively, and produce exactly the kind of effect that's required. In some cases it will be a lethal or destructive effect. In other cases it will be what some people call non-lethal. I prefer to call it unconventional, because there are very few non-lethal things that you deliver from aircraft.

For example, if you want to shut down a power system, like in Iraq, the accusation was that we denied power to a hospital. Well, if you could selectively take down a power distribution yard, a transformer yard for a period of time and it would come back on of its own free will after the effect wore off, then you don't have to pay to rebuild the country; you put people in a country at risk for only a short period of time.

Q: Do this electronically?

A: Electronically or by other means.

So the political implications of those kinds of attacks, if I can still use that word, are profound and can be great instruments of diplomacy for our government. They will require, perhaps, a different kind of decision process than we currently have, but the opportunities are significant.

Q: How do they break down? Let's talk about some of the technologies that can be used without telling people how to do it. What variety of instruments are available, based on the technology today?

A: We break the process down into steps. You have a requirement for surveillance, sensing that a target is present; you need to assess the information you receive; you need to pass the command to a shooter to deliver some kind of a weapon. New technologies that are applications of existing technology are in several categories.

First, we typically think of high explosive weapons, general purpose bombs which were developed in World War II, which are fairly inefficient, actually, and they weigh 500 pounds, a

thousand pounds, or two thousand pounds. The weapons that were used effectively in the Gulf War were primarily 2,000 pound bombs. Well, you are weight and volume constrained on the number of weapons you can carry of that size. It's possible with technology that we have today, to more selectively detonate a weapon so that you get the maximum amount of energy out of that weapon, and in the end, you're able to deliver the same relative effectiveness, with a weapon that's much smaller. So that is a technology. It's computer technology that allows you to do this. You're able to place detonators around a weapon much more effectively.

Other capabilities that exist are applications of what we call directed energy weapons, laser techniques. You've read in Aviation Week and other trade journals about weapons like the airborne laser for defeating ballistic missiles. This is very critical technology, because you have to be able to accomplish this task at the speed of light. You're talking about a very short period of time, and you want it to be certain, you want it to be swift.

There are the application of stealth technology, continuing to apply stealth technology to our delivery vehicles which may, in the future, not all be manned aircraft, but could be unmanned aerial vehicles, unmanned tactical aircraft where you take an aircraft system and drone it like we have in the past. But it can carry more payload, perhaps, than a UAV could, unmanned aerial vehicle.

Stealth is important, because you want to be able to persist in an area, survive in that area so that you can provide information to a shooter so that he can attack an incoming ballistic missile or a cruise missile that's coming along. Time urgent targets are of very great importance to us.

Q: So it gets very deep. This is a new vista, talking about psychological and a sociological change, even in the people who have to use the technology?

A: That's correct.

Q: A new way of thinking?

A: That's right. In fact I think something that people often either forget or don't realize is the psychological effect of massive bombardment. You can do that in many ways. Corregador is an example of massive ship bombardment. The bombardment by B-52s primarily in Desert Storm was a psychological weapon. The army, while it was tired and perhaps mildly demoralized to begin with, became very demoralized after it was bombarded day in and day out. Just the mere shaking of the ground and not knowing where the weapon's were going to fall will demoralize you.

In fact, we could say to them, if you are in that tank, you will die, and we're going to show you how. We'd fly over and put a laser-guided weapon on that tank and that tank disappears. Well, they didn't stay in their vehicles. When the vehicles stopped, they abandoned their vehicles. That's a psychological effect.

Also, the effect of being able to fly a system through an area and disable electronics, like your television camera, would simply shut down. You wouldn't know why, especially if the

vehicle were stealthy. Just all of a sudden everything shuts down. There would be a tremendous psychological effect to that. I think we have to play on those things.

Q: You talked about a lot of soft weaponry as well. Attacking the internal structure of a country like its banking system and so forth.

A: Yes.

Q: Is that one of the most devastating things you could possibly do?

A: Yes. That's often referred to as information warfare by some; and frankly, I have an aversion to slogans. It's a target. What's difficult about that, as powerful as it is, and it's extremely powerful, there's no country in the world that's more vulnerable or susceptible to that kind of attack than the United States of America. So we have to think about those kinds of things—both defensively and offensively. And we also have to think about the legality of it.

You need to have the options to conduct these operations, but on the other hand, there is a fine line between something that's illegal, an act that's illegal, and an act of war. People are trying to define that. I don't know the answer to that.

But one could interpret bringing down a country's banking system to be an act of war under certain circumstances. Under others, it could simply be viewed as an illegal act. Embezzlement, for example. Someone could take money out of an account.

Q: Of course they might not even know who did it.

A: They might not know who did it, and of course that would be the idea. You would want to have plausible denial; you would want to not leave a trail. You'd even like to be able to do something like that in such a way that it was disabled for only a period of time, to get a point across.

Q: So in this new world of technology where a lot of things could be purchased at Radio Shack, and everybody has the right to go to Radio Shack and buy them, who wins? Is it the richest company with the deepest bench, the most redundancy? Is that the person that survives?

A: Well, I think it's the person with a deep bench, a country with creative minds, innovative people, being able to prioritize the investments that they make, and that's a very different part of this problem, prioritizing investments, trying to predict what the right thing is to do for the future—something that has the greatest life.

I believe that we have come into an era of great capability leveling, if I can use that phrase. Until Desert Storm, actually, there really weren't many countries in the world that had the ability to have access to overhead imagery like we did, the communication systems that we have including satellite communications. Iraq was buying spot imagery. In fact the United States of America bought spot imagery for the war.

Now imagery, overhead imagery, navigation through GPS, and satellite communications, are all essentially public utilities. You subscribe to a service. You don't have to have a large infrastructure in your own country to develop the capabilities, you subscribe to it. So now even a country, a government, an entity that in the past would have caused us no concern we have to be concerned about. They have what some people call global situational awareness. They can buy situational awareness. It's a matter of money and how they apply it.

So the commercial marketplace is playing an important role. The commercial marketplace in terms of providing component hardware, processors, the communication systems that we use can push that technology farther faster than the Department of Defense can. There's no competition. So how we use that most effectively to lower cost and increase performance is a challenge, but it's something that the Air Force has stepped up to, and it's going to be something that's going to make our capabilities far greater at lower cost in the future, in my opinion.

Q: So what are your recommendations as your panel comes down to actually putting words on paper? What are you going to tell the Secretary?

A: Well, the tack that we've taken is that the only thing we really can say about the future is it will probably be different than today. We haven't got a crystal ball that's very effective.

What we've attempted to do is define what we call operational tasks that we think basically cover, we're going to say common military tasks. These are not just Air Force tasks, but common military tasks, or common tasks of the armed forces that need to be achieved in order to support the United States of America in its national strategic policy.

We think we're probably about 90 percent right on those tasks. So if we're 90 percent or 85 percent, that's good. These are stressing tasks that include activities like being able to defend against theater ballistic missiles or cruise missiles. To be able to deal with the artillery site in Bosnia. To assure the President of the United States that if I can find that target I can take that target out with no collateral damage and I can do it swiftly. To be able to provide survivability for the forces.

So we have these operational tasks, and we are making recommendations for capabilities to underwrite these tasks in components; sensors, platforms, and the weapons that would be used. And an important aspect which we call dynamic engagement control. You might think of that as command and control. We prefer to think of it as dynamic engagement control because we believe those words connote the urgency of the situation.

So we want to be able to tie together our sensors, which may be on board our platform or off board the platform to provide continuous, wide area surveillance of an area, to detect targets and create time histories of those targets—very important. A lot of these targets move, they have been called critical mobile targets in the past. Think of the SCUD hunt in Desert Storm. We need to be able to track those targets so we can give an update to an attacker, whether it's manned or unmanned, so they can find that tail and destroy it.

Time histories of various types of targets are very critical. The sensor technology to provide that on a platform that has persistence in an area—that means it stays around for a long time—and is survivable. It's likely that the vehicle of choice might be an unmanned arial vehicle. We can build that kind of thing.

We want to be able to have the sensor package on the unmanned aerial vehicle that can pick up a variety of signatures. It could be signals intelligence, it could be an IR image, it could be a radar image.

We want the ability to provide the country with a very rapid reconnaissance and/or strike capability at long range.

Q: Do you see that unmanned vehicle that can orbit for days at a time over a place as the adequate replacement for the SR-71 type aircraft?

A: I don't know if I'd use the word adequate. It certainly could replace it. If it's on station all the time, then you have on demand, the information that you need. It certainly could be viewed as a possible replacement. I wouldn't characterize it that way, only because I haven't thought about it. It certainly would provide on demand information because it was there all the time.

Q: It would be like having a TV station 80,000 feet overhead.

A: That's right. That's correct.

There are technologies that go with that kind of capability, not the least of which is propulsion. To have an air vehicle, a UAV operate at 80,000 feet or 100,000 feet, means we have to do some engine development. It's not something that's beyond the realm of possibility, but it's something we haven't built, an engine that can operate efficiently at those altitudes. That's something that's required.

Another area of capability that I alluded to earlier is the ability to defeat ballistic missiles, theater ballistic missiles. What's critical about this is, like one can subscribe to the public utility of information today, it's relatively inexpensive for a government or a country to buy or use theater ballistic missiles. That is as opposed to developing an air force. What's important about that is that if they have, or make you believe they have, a nuclear or biological or perhaps nasty chemical warhead for that weapon, they can hold a country hostage with that.

And if they shoot it and they have led you to believe that they have this capability, and/or you can't afford to take a chance that they don't, you have to intercept that weapon very quickly, and you have to intercept it over enemy territory. There are two reasons you have to do that. One is as a deterrent. Hopefully he won't want it falling back on him, so it might deter its use.

But secondly, if it does get fired, you want to intercept it in such a way that the debris, the fallout from the weapon, does not fall on territory that you don't want it to fall on, whether it's on your own troops or on a country that you may be trying to provide protection for. So theater ballistic missile defense is critical, it's a critical capability.

Defense against cruise missiles is just as important. You can make a cruise missile out of almost any air vehicle. You can take a cheap little airplane and drone it; you can take almost any missile that people own today and put a GPS inertial platform on it to guide it. It can cause terror if you don't, if you are not trying to precisely take out a target, you can still precisely provide terror against another country. You have to be able to do that.

The problem with cruise missiles is that they fly at low altitude, the troublesome ones are the ones that fly at low altitude. And because of their physical size, they're difficult to detect against a cluttered background, and, of course, you can do things to make them hard to detect. So this is a very challenging problem, to be able to pick up the cruise missile, detect the cruise missile, and provide an adequate queuing accuracy to ensure that the shooter can fire at this, and then have a weapon that can engage this cruise missile—again, before it reaches its target.

The ability to provide survivability through stealth technology and adaptive observability, perhaps it's a UAV, it could be a manned aircraft that you can change the signature of. Imagine, again, a psychological effect. Now you see it, now you don't. You don't know there's anything there and all of a sudden it's there, or you had something, you're tracking it, tracking it, tracking it, and all of a sudden it disappears. That has an effect on you no matter what the vehicle does.

In World War II there was a concept called "yahootie" lights, where they put headlights along the leading edge of a wing so it blended into the background. You'd like to be able to provide daytime stealth, visual stealth, to make a vehicle disappear.

Of course, nothing is undetectable—you can detect it at some frequency—the radar domain is still going to be one of principal concern. There are more radar-guided missiles than there are anything else in the world today, and they will probably continue to dominate.

You need to be able to deny the enemy the ability to detect and acquire you so that a tracking solution can't be created so that a missile on the ground can fire on you. We're recommending options for doing that that are different from those that we have today. For example, possibly using directed energy weapons.

The ability to deny the use of an imaging IR-guided missile against an airborne platform is very important. Today we use flares to deny IR-guided missiles, but when imaging seekers are built, the logic that is in the imaging seeker will allow the threat to write the software to process out the flare, so you need another way of damaging or degrading that missile.

Another aspect of it that's of great importance to us is dynamic engagement control, which just pervades everything that we're doing. But another part of it is that the ability to make the right decision in a timely way is going to be more critical in the future than it has ever been in the past.

When you're talking about having to engage targets in seconds or in minutes, you don't have a lot of time to think about it. If you are going to employ a weapon against an information system of some kind, then you have to think this through. You would like for our leadership to not have to think this through the first time when it's real use.

I believe that we need to provide a way for the national command authority to experience the decisionmaking process or processes that we think accompany some of these difficult decisions in real time under believable circumstances.

Now it won't be exactly the same circumstance if and when it ever has to be used, but on the other hand, we don't want the decisionmaker to get on-the-job training under these very important circumstances.

Those are some of the concepts that we're going to be recommending.

Q: What would Hap Arnold have thought if he could hear you talk today?

A: I hope he would be proud.

I think that Hap Arnold was a visionary. A very unique person, very visionary. If you consider the time in which he lived, he was a brilliant man. He happened to be an aviator.

He saw the need for thinking about the future in the 1940s, and he created organizations to help him do that. I work for one of them. I believe that he would be fascinated with *New World Vistas*. I think he would be bold in his decisions about what should be invested in in terms of research and development. And I think he would be bold about disinvesting in things that we're doing today to finance the future. I think he'd be very excited.

Dr. Michael Yarymovych

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Chairman, NATO AGARD

Chairman, *NWV* Space Applications Panel

"New World Vistas"

13 July 1995, The Beckman Center, CA

Q: To maintain superiority in space what will it require in terms of technology?

A: Actually, in terms of technology, it's really all there. It's not a question of developing new technology. Certainly there are many technologies which need to be improved, which can be carried forward to be more efficient, but actually, as a scientific group, as a scientist, you cannot project things into the future without knowing that there is a technological base for it. So the technologies are either in-hand or in the laboratory or at least in the minds of people.

Q: What is the weak point? Lift capability?

A: Yes, that is the weak point if you continue doing business the way we are. It really is a question of developing new ways of accomplishing our task to support the warfighter which would mitigate the problem of lift. Unfortunately, we have not yet found a way of developing much, much more efficient propulsion than we have. Now the chemical propulsion is limited to certain limits, certain chemical capabilities which translates into specific impulse, and only hydrogen and oxygen combinations can give you the best. After that, it's a matter of pulling it together in more efficient ways. But we have not yet discovered a new way of providing high thrust, high efficiency for space applications.

Q: Is quick turn-around a part of that equation, or is that something else?

A: Quick turn-around and your previous question, unfortunately, perpetuate some of the old paradigm that we're trying to change. So it is a question I do not want to answer. (Laughter)

Q: I'm getting into a tender subject, am I?

A: No, not at all. I would say, for instance, if you had a Smith Corona typewriter, manual typewriter, you would have said, "Gee, can I do something so I can type quicker?" And somebody would have said, "Yeah, I'll make it electric."

Then after awhile your fingers go as fast as they possibly can, but you still are only producing at the phenomenal speed of 100, 120 words per minute on a piece of paper. You want a copy? Oh, you put a carbon in there. Then you want to edit, well you take this paper and you erase, you cut and paste and retype it again. So that's quick turn-around.

Suppose I would tell you maybe you should do it in a different way. Maybe you should use a computer as a typewriter, and that maybe you could have real quick turn-around by moving paragraphs and words around on the screen.

Now to a Smith Corona manual typewriter designer, it would have been a totally unintelligible statement. And Smith Corona, as you know, last week went bankrupt. So I may want to lead you in a different direction than your questions. (Laughter)

Q: So let's do some new thinking about how we get into space.

A: What I would like to do is tell you that space is a different medium than the terrestrial mediums that we are familiar with—ground, sea, air. Because in the terrestrial medium, you move physical objects by forces, and when you don't move them, they stop. In space, once you've exerted the energy of accelerating an object, namely a satellite to a certain velocity, it will stay in orbit and it moves on its own without any further expenditure of energy. That's the advantage.

The disadvantage is that it doesn't hover over one place all the time unless you are at very high altitude.

In the past, the space medium has evolved from historical reasons on one hand, from the need to observe our arch enemy the Soviet Union, which led to rather large systems because of the important observational requirements. On the other hand, the access to space has evolved from the modification of ballistic missiles. Both of these are now 30 year old artifacts of history.

In the mean time, the most important thing that happened is the creation of the very high speed processor called the computer. Very small, very fast, they're everyplace. The world has taken off in an information-rich environment. It's happening commercially. The commercial use of space has gotten us into an era where space is very much part of our lives. Communications is commercialized, weather is commercialized, and since Desert Storm, positioning is becoming commercialized—high accuracy positioning. Right now, as we speak, commercial reconnaissance is coming along.

So the commercial world is going to provide to everybody—to us and our enemies and would-be enemies and well-heeled dictators—all the information that you need to conduct warfare.

Q: But if you use that commercial access in space, how do you use it in a secure manner?

A: Ah. The key question now is that we are going to be living in an environment of commercially-provided information. We have to assure availability of this information, assure our access to information, and that becomes a very difficult subject, and we are working this in our panel. Must you really own everything? Or can we rely upon the commercial systems, or should we own certain parts of it to make sure that if the commercial part comes down we can still conduct our operations? Or can we perhaps take over the system, which is probably not a good idea. You know the most reliable and available system right now in the information world is the telephone network—the AT&T network. You can hardly kill it. You can't kill it. That's assured its availability. It will be like this for many things in the future.

***Q:* So if you use encryption, you use redundant commercial systems, you have your access to space, and probably on a fairly guarded basis. Everybody can buy it, though. Everybody.**

A: Exactly.

***Q:* How deep does a big, wealthy nation like ours have to be in order to have a deep enough bench to sustain the attack by the other guy?**

A: That is another key question. I can see a near future with proliferated weapons coming out of the former Soviet Union. They're on the market, thousands of what used to be fairly sophisticated weapons, but they are kind of old fashioned by now. But I can also see a well-heeled dictator going to the Radio Shack and getting the computer, getting the GPS receiver, screwing it on, and now have a weapon that will give us a hard time.

That's quite a dilemma. And just turning off the commercial systems by blasting them out of the sky or whatever is not the answer, because there are a hell of a lot of other enemies in the world, but more importantly, there are a hell of a lot of other friends that we don't want to disable.

An example is the GPS that provides you high accuracy data. Well, here you have a low intensity war which is probably a more predictable event, in Somalia. It's not really a national emergency, so you don't really want to all of a sudden turn off the GPS service that's been purchased by commercial airlines, and there is an airliner coming in for landing in Singapore who can't land, just because you happen to have a police action going on in Somalia. Which says that we have to find ways of local control. We have to find ways of owning the information sphere in our battle zone. That comes through various techniques of jamming, encryption, and power.

***Q:* Creating a protective bubble?**

A: So that we can use these systems to our advantage, and we can deny the use of the systems to our enemies.

***Q:* I would like to know if you could summarize how your panel will write the report and what your basic recommendations would be?**

A: Our basic conclusions and ensuing recommendations can be classed in three areas. One is that space will be the key medium of providing ubiquitous information to our warfighters to carry out their missions at really arbitrarily good accuracy during all weather, day/night operations.

Having done that, we think that this then becomes a very important asset which will in turn be vulnerable to attacks and disruption by our adversaries. Conversely, we may want to be able to deny the use of that asset by our adversaries. Therefore, the second recommendation is that we have to develop techniques for space control to be able to have this medium either denied or available to us.

Having done that, comes the next level of sophistication; providing capabilities for global power projection. From space we can exact our military force at any place on this planet.

Those are the three key observations.

Q: I don't hear anywhere in any of that discussion of human access to space.

A: That's a question that's before us all the time. We have discussed this quite a bit. We find that it's still uncertain whether the physical presence of man in orbit adds anything to the game, considering the fact that the man on the ground via the space medium, has presence anyway.

We are encouraging NASA to continue working on manned space flight. We certainly expect man to be very useful in the exploration of the universe where you have distant places where the communications are delayed and where the man needs to look for unexpected events—you have to transport the brain with the body.

In military terrestrial operations, the communication delays are so short that speed of light probably will not require the man to be physically present

Q: Quite fair enough, and you have enough redundancy that if there's failure you can switch to another channel.

A: Yes.

Q: So you feel satisfied that from a warfare standpoint, space is best conducted, or best operated from the ground.

A: Yes. As a matter of fact, we often make the mistake when we say space, we say satellites. I want to be sure that we exercise discipline. When we say satellites we actually mean that particular object that's flying in there, whether it's far from the whole system. We're talking about space systems which by themselves, satellites are worthless without the ground system that controls it, without the ground system that tasks it, without the ground system that receives the information. For that matter, when we talk about the world bathed in information, or bathed in data that has to be converted to information, the sources to the warfighter are myriad. It's a system of systems. A space system, with an aerial system, with UAVs, with ground sources, and all of this together then provides the picture to the warfighter.

Q: And you also suggested that satellites should be considered squadrons, I believe.

A: Not really, no. As a matter of fact, maybe I have quite awhile ago in my life, and I'm getting a little bit beyond that.

I do believe that one of the other technologies that's moving forward quite a bit is the ability of satellites to work together with each other in distributed systems. Rather than thinking of one single big satellite and high altitude orbit, they perhaps can be replaced with numbers of small satellites that move around but internet with each other. If you wish to call that a squadron, well maybe you wish, but it's not quite as correct a word as I originally thought it was.

Q: You were chairman of one of these sessions in the '70s. How is this approach different from when you were running the program?

A: At the time we were doing *Towards New Horizons II* (TNHII), and it was 1975. At that time the study was conducted primarily within the Pentagon. The sources of information and data were mostly derived from the military officers who were either on duty in the Pentagon, or we brought in quite a few smart people from the commands to participate and give us their views. At the time the word warfighter was not the current word, but still the operational views.

We had also a major section of that report devoted to the view at a future world, meaning political. Will there be a Soviet Union, will there be a new threat? That was a large part of the exercise. Then we tried to match technologies to various scenarios of big war, middle war, small war. That's probably the difference.

Q: Today you have a different breed of Air Force scientist too, don't you?

A: Well, it was at that time already beginning. Certainly in Kármán's time there were Air Force officers who were fighting men, they were soldiers, and then there were scientists who at the time barely understood what military things were all about. Kármán put them together to make them talk to each other, but by doing this he also created an infrastructure within the Air Force and a desire for pulling the scientific skills into the military force. So we have now a cadre, already a second or third generation of officers who are technically very, very competent, and it is no longer this business of "we" are the scientists and "they" are the military guys.

Q: Then there's a third element, the high speed computer, which has come into its fashion in the last few years.

A: Yes. Well, would you believe in 1975 when we produced this report, (TNHII) the key conclusion was that we were about to enter the world of computational plenty. This was at the time when the IBM 360 was the new thing. And there were, I have to admit, there were quite a few skeptics who thought that it was totally unaffordable and unthinkable to have an IBM 360 on every base and on every platform. As a matter of fact, the AWACS became a very important airplane because it carried an IBM 360, which incidentally, it still does.

So it's only 20 years ago that the projection of the world of computational plenty was considered to be outrageous.

Q: Fifty years ago Theodore von Kármán and Hap Arnold set all this thing in motion through their own vision. What do you think they'd think of if they could see what's happening today?

A: Yes, clearly they were very intelligent, far-sighted people. Given the new facts of the creation of new technologies that at that time were not even thought of, they would have probably come to the same conclusions that we do at this moment. Perhaps with the exception of not focusing so much on the preparation for the next nuclear war.

Let me then perhaps sign off with this point. That just like they at that time, we are also at this time limited by our view of the physically possible. Yes, we try to look for discontinuities or

breakthroughs, but by definition, a breakthrough cannot be predicted. So tomorrow at some university campus someone can walk out with a discovery, and it will change everything we just said.

Dr. Curtis Carlson

Executive Vice President at the David Sarnoff Research Center
Chief, Interactive Systems Division

"New World Vistas"

5 September 1995, Sarnoff Research Center, Princeton, N.J.

Q: This is a long leap from a bunch of officers standing around a sand table moving things with a pointer. Here you have the possibility to get a complete, real time view of what's happening in the battle theater.

A: That's correct.

Q: What kind of a leap forward is that in terms of the technology we have available today?

A: It's a leap forward in a couple of ways. One way is in terms of the displays that you see behind you. [Virtual Reality Battlefield Displays]

One of the things you want to do in a technology like this is immerse the person. So you see a surround environment, so you can see all the information that's available. That's a key thing. That's the first thing.

The second is the computers that drive the technology. Obviously, they need to be powerful to fill up displays of that magnitude.

But the third part, and the part that we're spending a great deal of time on is the user interface. How do you present the information in the way that's most persuasive, most meaningful to someone who has to confront the massive amounts of information that are on the screen behind us right now.

Q: You used the word immersion. Is that the key?

A: Immersion is one of the keys, so that 3D becomes an important piece of this technology. So that not only does it surround your periphery, it surrounds your whole visual field. Also, the 3D gives you a sense of depth so you can disambiguate the information. That's important for someone who has to make split second decisions. They have to figure out whether a plane or a ship is in front or in back of the other, and there are lots of ways you can do that, but when seconds become the critical issue, and they do in these kinds of environments, every clue that you can give the operator, including 3D becomes critical to the success of the device, some initiative.

Q: Where does this have to be? Does this situation or this setup have to be at the location? Can it be in Washington, and that being taking place on the other side of the world?

A: It will be everywhere. It will be on the ship. It will be used increasingly by individual operators on the ship who will have pieces of this. The commander, of course, will see the overview of this when appropriate. Pieces of this, or in fact the entire view, will go back to Washington, and there will be people who will be able to do that. Other ships will be able to have it. It will be a question of where is the best place to allow you to see the particular view of the battlefield? That will depend on the mission and the technology will let it become possible to put it anywhere.

Q: This is, of course, going back to Washington, I assume, by satellite, and then it's almost instantaneous real time, isn't it?

A: That's correct.

Q: Where is it going? This is so fantastic as it is, where does it go from here?

A: Well, it obviously gets incrementally better in the sense that you can imagine bigger displays, brighter displays, more information, faster. But ultimately, we're moving to not only the use of this technology, but it being very, very low cost, and the cost has a big impact because it means then you can make it ubiquitous in the sense that we were just talking about.

Let me give you an example of what's happening in the home, to give some sense of where this technology is going.

Right now everybody knows about high definition television. Everybody knows about video server technology that's being developed that will let you have access not to just a couple of movies or a hundred movies, but literally tens of thousands of movies, so that you will be able to sit there on your couch with a device very much like your VCR control that will allow you to have access to all those movies, fast forward, stop, and reverse, and you'll be able to have that at consumer prices.

Now those technologies are the ones that are going to be layered on top of the kinds of technology you see behind me to allow this to be deployed in the field very cheaply to soldiers and sailors so that they can begin to take advantage of this in new and more and more powerful ways.

Q: Does it require dedicated systems? Can the DoD avail itself of commercial systems to make this link between the battlefield and the Pentagon?

A: That's a really important point.

The world we're going into, DoD is not the exclusive developer of these technologies any more. In fact most of the activity is happening in places like Sarnoff and Disney and Intel and MicroSoft around the world. That's good news for DoD because it can access those technologies, particularly the consumer technologies, which will be digital, and unlike today's technology, bits are bits. So you can use not only the technology for television, but you can use it to transport

images or logistical information or mission planning data or downloading software. That technology will be applied and available to DoD.

One of the challenges for DoD is to aggressively exploit those opportunities that are going to happen around the world today.

Q: With encryption, guarded circuits are not a problem, are they?

A: Right. Various levels of encryption should be able to protect this information, particularly for DoD kinds of applications.

Q: Doesn't the mere widespread proliferation of these kind of communication channels, doesn't that protect the circuits to a certain degree? How do you pick out what's what?

A: Well, it's going to be an interesting challenge for DoD. The proliferation does mean that there are options, so that it is hard to track information. It also means you have multiple ways to send information back. Those are all good. That's good news.

The difficult part of it is if you're trying to find a piece of information in that maze, it obviously becomes that much more difficult as well.

Q: During these interviews we've heard a lot of people talk about the commercial aspects of all of this and how the DoD should be using more and more of it. Do you see this as a turning point in the evolution of science and technology? During the early 1950s and 1960s, DoD was driving a great deal of the R&D in this country. Now commercial is leading.

A: Right.

Q: Is that healthy?

A: It is healthy. Part of it is inevitable.

I'm reminded of one piece of data that's come out of the Commerce Department that shows that in 1990-92, for the first time, the U.S. economy spent more money on investment on information technologies than everything else. So by that definition, we officially entered the information age in 1990-1992 era.

It's also interesting that for the first time video, which was the last primary data type that was analog, went digital. We have entered the digital information age. The growth curve for information technologies is increasing, doubling every five to seven years.

DoD's budgets are basically flat, and they're going to remain flat. And the information curves are going to continue to double every five to seven years.

Well, the government needs to change its paradigm from when it was a developer of technology to a user and exploiter of technology. The U.S. government is now like any other really big company that develops some technology which gives is a proprietary edge, but must leverage and use all the other technologies that are developed around the world. That's a different

mindset, but it's an important one, and if the U.S. government does it properly, I think it can maintain its competitive advantage.

Q: Doesn't that expand the size of the Air Force, the information expansion, the availability to access more information, even when you're downsizing? Doesn't that expand its capabilities, and in so many words, its size, because it has an expanded reach?

A: I believe it does expand the effective size of the Air Force or any of the services in the sense of every other company today basically has become more of a virtual organization where they tap into the best resources around the world. Or they tap into the information sources around the world, wherever they may exist. Or they tap into the communications and the computing infrastructures wherever they exist.

If you change your point of view so you can use these new, expanding capabilities, then I think you're right. Instead of looking at a constructing or a downsizing of capability, you can think of a much more powerful infrastructure moving forward. The best companies in America today are doing that aggressively and succeeding worldwide.

Q: Yes, those companies have become global.

A: They have.

Q: So has the Air Force, even though it is more localized than it used to be.

A: That's correct.

Q: It has a global intellect.

A: That's correct. And increasingly, that will have to be the perspective not only of companies, but also of the Air Force and the other services.

Q: What happens to the shape of warfare in the 21st Century? Because of the information revolution that we're now undergoing, what will it look like? We hear a great deal of discussion of non-lethal weapons. We hear a great deal of discussion about information warfare in which you get into the other side's communication system and shut them down. Is that where you see it going?

A: I find it hard to predict the future in this world where computer power is changing by a factor of 100 every seven years. That's a revolution in the computer world.

As I mentioned earlier, we left the industrial age officially at around 1992. Now we've entered the information age. So now in terms of the impact that it's going to have on us, we're going to have this exponentially increasing capability and impact on the world. So I think anybody who makes predictions about the future has to be a little careful today.

But I would say that if you look around you at the impact that information technologies have had on you and the impact of things like computer viruses and other forms of agent

technologies are beginning to have on us, it doesn't take too much predictability to say that the world we're going into is one where the information technologies are going to be dominant, where there will be new forms of opportunity, access to information, but incredibly sophisticated threats—whether it be information warfare or more benign things.

Norman Winarski

Division Vice President of Sarnoff Research Center
Information Sciences Laboratories

"New World Vistas"

5 September 1995, Sarnoff Research Center, Princeton, N.J.

Q: When did you come to work here, Mr. Winarski?

A: I joined in 1976 while we were still RCA. Since that time we transitioned into GE, and then into the Sarnoff Research Center.

Q: Since 1976 what have you seen the technology do? It's almost been standing on its head, hasn't it?

A: Yes. Technology has made profound changes in virtually every area of human experience. Now we see display technology, video technology, communications technology and computing technology, all having a revolutionary impact in the last few years, actually, there's been the greatest change in the '90s.

Q: The Tofflers call this a "civilizational upheaval." We've had another one of those turning points in our evolution, I guess, and we're now in a chaotic period of learning and transition into some other kind of society. The high speed computer that has made so much of this possible is now even changing the way we're thinking about conducting warfare.

A: It is. We are seeing changes in every aspect. For example, the high speed computer is not only enabling new types of warfare—information warfare—it's enabling new capabilities in warfare. Information that will be used for medical environments, for example. A major new aspect will be the ability to do distance triage.

Q: Tell me more about that.

A: For example, you would like to be able to bring the eyes and ears and experience of a physician to the field and start to explore and experiment. It would be nice to bring the eyes and ears and experience of a physician to the field to be able to understand quickly the condition or state of the warfighter and be able to make the right decisions at the right time. Distance technology that allows you to see and even touch and sense all the different capabilities, all the different life signs.

Q: I understand what you're saying, sure. You're able to do it by remote, by television, by satellite.

A: Right.

Q: We are able to be in touch with the patient.

A: Right. In fact an ARPA representative talked about distance operations and how what used to be blood and guts in the past is really just bits and bytes today. The idea here is that you can actually feel like you're sensing information, you're sensing the full experience, but in fact that can be a remote experience. And you could still operate with your full knowledge of the whole problem.

Q: What is the advantage of the UAV? We're looking at stuff behind you right now. What's going on here?

A: UAV technology is going to have a major impact on our ability to fight wars, and also in the consumer and commercial worlds. The reason for this is that they can dwell, they can dwell over sites at low cost. Since they're unmanned, they will allow us to put aircraft in situations that may be rather dangerous. Since they're unmanned in different ways, different tactics can be employed. In fact, on manned tactical aircraft that ARPA's talking about now, you could consider rather aggressive tactics—more G's than an air fighter can take, for example.

So the ability of unmanned vehicles to go into dangerous areas and to explore and seek out and sense all the information that's needed to fight the war is an unprecedented capability.

Q: These images behind you right now, what are they?

A: In this scene, what you're seeing is the local information coming from another helicopter that's looking at two different helicopters. One is camouflaged and one is not. The concept is, how do we have a system that can analyze and understand in real time where those helicopters are? Motion tracking and target detection.

What's happening is frame by frame, in real time, those images are being aligned. The difference is being taken. Motion of the camera itself is being accounted for. So only the motion of the target remains. That way even with a camouflage target, you can easily sense where that is.

Q: And this here, is that another example of that?

A: What you're seeing here is that target detection. And what you're seeing is, in this strange inverted pyramid, is in fact, the same way the eye sees, coarse resolution, finer and finer and finer. Your peripheral vision, as you move toward your phobial vision you get closer and closer, finer and finer resolution. What's happening is the computer is processing at very coarse resolution the image, looking for changes. Then at higher resolution, and higher and higher.

So what you're seeing in real time is the computer looking and finding the changes in motion, extracting the change in motion of the camera itself, and finding the targets.

Q: Wow. Mosaic photography. As it builds up, as the UAV flies over a territory. What's going on there?

A: Imagine as a UAV is flying over territory, that the camera is locally giving you information, but that you are not getting a global view, other than, for example, a map that is nearby of what that camera is seeing.

What we have now is the capability to take those frames, as they are coming from the UAV in real time, and they're coming over time, and we can align them in space. So as they overlap, we can in real time register and align the next and the next and the next. So you see an unfolding of a video as a panoramic mosaic. In fact that mosaic in real time could be fused to an underlying image so that you can see the new information that comes from the UAV updated on the underlying satellite image, for example, as it's unfolding.

Q: Fifteen years ago, what would it have taken to do a thing like that?

A: Well, first of all, neither the algorithms nor the computing power were possible 15 years ago, so I would say it would have been impossible 15 years ago. But assuming that people actually invented these algorithms 15 years ago, the kind of computing power it would take would be super computing power and maybe tens of them. That might not be sufficient.

Q: Where is this all going? You have an immense power right now. You have an immense capability. But with the technology expanding as rapidly as it is, in your fondest hopes when you're sitting in blue skying at your desk each day, what do you think it's going to lead to? By the time you retire from this company, what will this kind of thing look like?

A: I believe that much of the technologies that we're seeing today, such as the mosaicing technology, also fusion technology, change detection as you saw earlier. These technologies are going to advance, first of all, in performance, so it's going to be even more robust for say the home movie taker, who now wants to take their home movies of their scene in the beach and create a panoramic high resolution photograph of the beach.

So what we'll start seeing is the ability for these technologies, originally funded by the government, to move into massive commercial use and consumer use. What you'll see is the videoprint, for example, the capability to take a video and create a high resolution print.

In terms of change detection, you'll be able to start using that for mamograms, as an example, where you can look and detect cancer in its earliest stages by aligning mamograms to each other and differencing them, so that you can get that early detection.

So I believe that what you'll see is for the warfighter, first of all, lower cost and higher performance means that we'll be able to distribute this capability to the warfighter and give an entirely new capability to manage and see the battlefield, and allow the warfighter to get the information that they need and be able to fuse it into a global view and to use that global view in the context of all that's unfolding from all the sensors. So having a battlefield awareness that will come from a global set of sensors, all fused into a single view. That's one thing that will happen for the warfighter.

For the commercial world, you'll see an explosion of technologies that allow all of us to go well beyond the capabilities today of existing cameras, for example, where camera will become smart and enable them to sense who you are, and you could walk up to your door bell and it would say, "Hi, John. How are you? Come on in." And cameras that will be used for medical applications so they can be taking images in operating rooms and tracking where the patient is and fusing, perhaps, where the lesion is in your brain so that they can operate and see what they're doing.

In fact one of the greatest consequences of the virtual reality programs will be in medical areas.

Q: When you were a kid did you read science fiction?

A: I did. I love science fiction.

Q: Is it here now?

A: Well, I wouldn't call this fiction. What's here now is closer to science fiction as it was predicted when I was a kid than science predicted. So what I would say is the Dick Tracy watches that you used to think that you could communicate—well, that's closer here. I think people believed in science fiction more closely to what we are today than they actually believed in science.

I once talked to a person in the telephone company, not too long ago, actually, about what they saw, their engineers saw, as the next stage in switches, telephone switches, when they had operators. They said it was obvious. It was robotic operators that were moving the switches.

So the concept here is that inventions in science have evolved in a revolutionary way, and they haven't evolved from previous obvious concepts, so we see wholly new capabilities that we wouldn't have seen any other way. And science fiction writers tend to be more creative in their imagination.

Q: Isn't the computer, in fact, the robot butler we all thought we were going to have?

A: The computer is enabling us to begin to talk about that capability. The human capability to assist and interpret tasks and understand the full concept of the event is still not reachable by current states of computers, and maybe never will be. But certainly computer tools to assist the human in all their tasks is what we're seeing begin to unfold in all the ares of human experience and work.

Q: Based on what you see each and every day, and the thinking of the minds in this building around you which are exceptional, what do you think the United States Air Force will look like 30, 50 years from today, and what will be its purpose?

A: That's a great question. I think that vehicles will be widely different from what they are today. Unmanned vehicles will become certainly commonplace, and varieties of unmanned vehicles that can perform tactical maneuvers or survey the ground are going to be critical.

There's also going to be a great deal of interpretation and understanding about what is happening to aircraft. So important information will be selected and determined and acted upon in real time. Real time meaning as fast as it's sensed and processed, often at 30 frames per second.

I think the Air Force will have a great capability to understand the battlefield in some new fused view that can come only from multiple sensors in multiple geographic regions that enable them to be able to understand the battlefield and then react in entirely new ways.

I think their capability to react will come from wholly new abilities to deliver weapons. We've begun only now to begin to see the smart weapons that are unfolding. With the onset of new capabilities, consumer and computing capabilities, more and more you'll see things like GPS and down loadable computers and smart cameras in these Air Force vehicles and in the weapons themselves.

I believe that the capability to extend human reach from not only the aircraft, but from the ground, will also be a fundamental new capability. I think pilots will not only fly aircraft in the air, but they'll be sitting there on the ground flying those aircraft. And when they are, they'll be able to bring the best judgments of multiple pilots and call them in so that they can understand and analyze a new situation as needed. Or, for example, one pilot could actually man ten aircraft if not much is happening. So it will wholly transform the ability to understand the battlefield situation and manage their flights.

I think that there's a great opportunity for the Air Force to understand and evolve in this new battlefield arena. I think that this is the information battlefield, not just the blood and guts battlefield that we're talking about. Perhaps new wars will be fought just as much with information as with bullets.

If that's true, then the Air Force needs to understand its mission as it relates to information warfare as well, and how it would be using these tools together with all the weapons that they have in their arsenal.

Q: You're speaking of warfare of dominance. In many cases that's intellectual dominance rather than force dominance, isn't it?

A: That's right. Basically I believe that if you understand the events that are unfolding in a global context, then your capability to influence that warfare is enormous. So it is information dominance and knowledge dominance that will, in fact, be the predominant way to win a war.

Dr. Garrison Rapmund, M.D.

Chairman, *NWV* Human Systems/Biotechnology Panel

"New World Vistas"

13 July 1995, The Beckman Center, CA

Q: Dr. Rapmund, there are so many things that are in the realm of beyond today's technology that are going on, but the one that really grasped me was the idea or the prospect or the theory that a person could steer an airplane or cause it to do certain things just by thinking about it. Is that possible?

A: It is barely possible now in a laboratory situation, but I think it might be very possible in the timeframe of this exercise, say by the year 2020 or even before. It all depends on the function that you choose to try to automate in that way.

Q: So at least in theory, people know that it can be done and there are resources within the brain that can be tapped to do that sort of thing. Why would you do it?

A: Well, from a military point of view, any task that can be automated, any task that can be reduced in the number of components it takes to accomplish, the better, because in many military environments, especially in the cockpit of a very fast airplane, there are a great many things that the pilot has to do. If we can reduce that workload or help him shift the responsibility for some functions from totally his to a partnership with an automated system, so much the better.

Q: For instance if a guy was pulling high Gs and he really couldn't move too many parts of his body, maybe it's a good idea to be able to think about it, is that right?

A: That's true.

Q: How is it possible to do that? Does the brain give that specific a signal that you can tap into the right signal?

A: Well, it involves mapping of electrical signals that are generated in the brain. It also involves filtering them so that you get the right signals. That's where the research people are focusing their attention, to improve the precision of the signals that they're taking. Then they, of course, after collecting them, they process them and amplify them, and then transfer them into a control device.

Q: Can anybody do it? Does it take a special person? Is everybody's brain so quick?

A: I think the answer to that is that with training, many people can do it. It involves the basic principles of bio-feedback, and then clever signal processing, and most importantly, matching the technology to a doable task.

Q: In any kind of research like this, there are fall-out items that are of interest to other people in other fields.

A: Well, in this particular line of research, probably not. But I can think of activities outside of the Defense Department that are quite interested in these technologies.

Q: For instance?

A: Well, for instance, the videogame industry. Just the idea of being able to think and shoot in the context of a videogame is pretty exciting, and I think whatever age the player is, they would get pretty excited.

Q: I think so, too. How about Alzheimer's and that kind of research. Is there any concomitant research?

A: We're talking about the degradation in human brain function and certainly some of the research that the Air Force supports will have a direct benefit to patients with Alzheimer's. An example might be the better understanding of the function of memory, because in Alzheimer's there is a deterioration of memory. At the same time, memory is very important as a function in understanding and remembering the situation in which you're operating, so there's a direct linkage between a benefit to a very important segment of our population and to our national security needs.

Q: If somebody had told you that this kind of research could even be contemplated say 20 years ago, what would your answer have been?

A: I certainly would have been surprised. Maybe less so if you said ten years ago, because the explosion of information in neuro-science, the general field of neuro-science and the subfields, would predict general advance, making it possible to fantasize that some of the things that we've talked about will actually happen. Maybe not in the way we will think about it, and there will be some surprises.

Dr. Kary B. Mullis

Director, Institute for Further Study
1993 Nobel Prize, Chemistry

"New World Vistas"

16 July 1995, Mendocino, CA.

Q: Dr. Mullis, looking at the future, which is where you spend most of your time, what will the Air Force look like 30 years from today, and what should it look like?

A: It's a question that I like. I think we're pretty much done with serious wars. But I think we're just a little speck in a much grander kind of a scenario that's not just science fiction, it's real. There are other forms of life in our galaxy, and they are not likely to forever ignore us, if they have so far. I like the comfort of having an Air Force around. As we expand our horizons, we're not going to find necessarily that everything out there is benevolent. It sounds ridiculous to people that think of themselves as serious planners on the global/political scale. It probably sounded really ridiculous to people in the South Pacific in the 17th Century that suddenly very sophisticated and not terribly benevolent people were coming in various kinds of ships, bringing their own bibles and their own set of laws and imposing them right there on the spot, bringing their religion and their own way of life.

It wasn't such a good thing, always, to be colonized. I think although you can't really reasonably expect to be prepared for what it is that we're going to run into because it's not going to necessarily be like Star Trek. That might not be weird enough. It might be even weirder than that, but we can't be prepared. But we can be as prepared as we can be.

I don't think we should put all of our resources into getting ready to be colonized, but I think a little bit of a military front is really a good way to deal with the first contacts with extraterrestrials, and it's ridiculous to think that we're not going to do that.

Q: Given that scenario, what function does an Air Force perform? How does it fit in?

A: It can preside over the protocol. If you don't have one, how do you deal with this sort of thing?

When you go to another country, even a friendly country, you don't want to bring out your big armament, necessarily, but you want to have the feeling of, "Well, if you guys are not going to be friendly, we can get back on an airplane and leave in a style that we want to do. We're not helpless."

Like I said, it's ridiculous to think you could prepare for what's waiting for us out there, but you can be more prepared than less. You don't want to go out there naked and say, "Here we are, what do you want to do with us?" Because what they want to do with you may be nice, and it may not be. It's like you want to have a little choice in the matter if you can, and at least put up that sort of impression that we're friendly, tentatively, but we don't think of ourselves as helpless.

We've got weapons here that can make a mess out of this place so it won't be much fun for you to walk in and take it over. That sort of thing.

You don't want to be too belligerent because you're up against the rest of the universe. But I think that history on this planet has shown that you don't just welcome with open arms every foreigner and say come in. Here's our wives and girlfriends and our food and our houses and you're welcome. We know you must have decency in your heart, because you're strange looking. I don't go for that.

I think a lot of cultures that we'll run into over the next say 100,000 or 200,000 years will probably be benevolent. They will look at us the same way that we look at, maybe some of us here, look at the whales. An interesting alien race that should be respected in a sense. But there's also going to be other influences. They have teenagers. There's going to be vandals in the universe.

It's not going to be any different than here, it's just going to be on a much grander scale. Sometimes you want to have, just like in the Anderson Valley here, as peaceful as it is, it's nice to have a sheriff around sometimes, just to make sure that when things get out of hand you can call him and say hey, come over here and bring your pistol. There's a guy that won't go away, and I don't like him. He's on my property.

I don't want you to come over here and drop a bomb on me necessarily, but it's good to have some security. This sounds funny coming from an old Berkeley guy, but I think we can't afford to think that we're alone here in this galaxy, and there's got to be things out there similar to us, and if they're enough similar to us, then there are some bad guys, too.

Q: You would have to think that anything intelligent enough to reach us would be something you would want to deal with.

A: It might be a criminal that's intelligent enough to reach us, and he might be running from their law. We don't know. But I think the best way to try to imagine it is more of the same. More of what we know in terms of what intelligent life does, and intelligence is sometimes not the right word. But capable life. You don't know what's going to be, what you're going to end up meeting.

Q: Are you in touch with the SETI (Search for Extra-Terrestrial Intelligence) Project?

A: I know about it. I'm not in touch with them. I guess they're trying to reach me out here, but... (Laughter) I read about stuff like that, but I'm not involved in it.

Q: Let's talk about the near term. This Air Force right now is on the cusp of some very dramatic science in terms of what the computer has been able to do for them. They're looking at new weapon systems that are based on a non-lethal stance, at least as non-lethal as a weapon can be.

A: Stun.

Q: Yeah, stun, or immobilize, or shut down a government. What's your vision of that kind of thing?

A: I, for a long time, really championed the concepts about industrialization of space. One of the things I thought about was putting giant reflectors up there to catch the rays of the sun 24 hours a day, and beam it back down as microwaves and use that as power. I think that was a really good idea.

Another use for those same things, you could put fairly stringent diplomatic pressure on a capital of some country that's giving you a lot of trouble by just saying, "We're just going to turn those things on you for a little while, and it's going to get warmer every day. When you look up at night, you're going to see these bright little things, and they're reflecting sunlight down, and you probably won't like it after awhile." I mean, mild pressures that don't really kill anybody, that give you plenty of time to get out of there, but your capital is going to be in flames pretty soon.

That's a high tech solution to a problem. What do you do when a country is just really being a pest in the world? There will be a continual need for that sort of stuff.

Q: That's weather control?

A: Yes. It's scary, but it's part of life. Conflict is not over even on this planet. I think we need to continue to think in terms of how you deal with people that are established in some place and that are really kind of criminal about the way they do things, but they have control of some country. It's happened here. It happens everywhere. It's a social problem, in a way, when it's happening in your own country, but it's not a social problem, necessarily, when it's happening some other place when you can pretty easily identify where the source of the problems are and who is being abused by who, that kind of thing. You need that kind of ability to apply gentle pressures that get worse and worse, but you don't ever have to say, okay, we're going to call in the jets. That's big, a serious change. This is sort of a mild kind of thing. You'd better think about this. In every case, it's going to get worse.

Q: So no doubt, in your mind, the resources of the Air Force need to expand into the space envelope—even more actively than they are now.

A: We're going into space. Whether the Air Force goes with us or not. Industrial kinds of things are going to get us into that. We're an expansive kind of population. Nobody's stepped on us yet, meaning people. We're spreading. Space is an excellent place for a tool using people like us because you have accessible energy, you have cold if you want to have cold. If you want to make a turbine that makes electricity from sunlight out there, it's a snap. You put up a little sun shade, and you've got minus 273 degrees. It's very cold on the cold side of the turbine. You stick a little reflector on the other side, and you've got as high a temperature as you want—for cheap, for easy.

To make things out there you can move big things around. Once you've got a place that's full of air and you don't have to have a space suit on, to do construction out there is going to be really easy. All you need is material, which you can get from all over.

There's all kinds of books about that stuff that excited me along time ago, and still do. It's so obvious that that's where we're going.

Q: How do you feel about the cooperative efforts between the United States, Russia, Europe, Japan, now towards an international space station. Is that a good first step?

A: Good. That's a real good first step.

Q: Who's the arbiter in this kind of a decision? When you start using weapons from space, you're really getting into everybody's back yard to a bit. Who's the real arbiter? Is the United States because we're so rich and powerful, the proper instrumentality to make decisions like that? Is it a UN?

A: I don't know what the proper one is, but reality is going to have a way of exerting its own force, and it always does. There will be people up there that can look right down into your yard with satellites, and whoever owns them and whoever's in touch with them, that's who's going to be watching you. There's not really any way you can enforce, forever, a ban on that kind of stuff.

There are already things there that can read your license plate. Who's running them? Whoever put them up there, that's who's running them. I think we might as well just get used to the fact that as technology advances, privacy is going to vanish unless you want to have actively filtered your little environment from anything like that.

I have a real "science fictiony" kind of viewpoint on things, but never, in the last 300 years, has that kind of viewpoint been shown to be wrong. The guys with the craziest ideas in the last 50 years are saying, "I saw that coming." It's the Jules Vernes-types who are really talking about the future—not the planner for the Air Force necessarily. Although they should listen to the science fiction people because those are the guys that are thinking about it, and it does have a way of happening. When you can imagine something 50 years later, it's happened in space.

Q: What bothers the ordinary person about science fiction, I think, is because of the immensity of doing the things that are described there. Here comes the high speed computer, however, which has changed our way of thinking about a great number of things. These things become more possible because pretty soon there's no reason not to do them. Is that the way you look at it?

A: No reason not to. I think a lot of times people think of reasons not to do them, but you just can't stop it. You can't police the world, in a way. You can't really keep people from being people, and that's what people do, is they make new tools and they use them. You just have to get used to that and not worry about it so much because there's nothing you can do about it. Get prepared for it if it needs you being prepared, but I don't think there's any way you can legislate it out of existence. This is something that's been with us from a million years ago or so. We started doing that a long time ago. We're not going to stop now because somebody writes down in a book somewhere that we shouldn't. People don't listen to "shouldn't." I'm not being cynical, I just look at history and say well, what if they had said you shouldn't take ships over to the

Western Hemisphere because it wouldn't be good? It wouldn't have stopped it. Even if England had said you should not do that. We'll blow you up if you try. Eventually, somebody would have done it. It's always going to be that way. Whatever you can imagine, humans are going to experiment with, they're going to try it. All along the way, devastation will be wreaked on a lot of people because we're experimental with our lives and with our projects.

But somehow, out of all that, if you have any faith at all in evolution, and I do, the forces of life are eventually going to end up being like what we have here. What we are now. It's not going to be a whole lot different. It will have different fittings, different little tubes, different things to look through. But the quality of life I think will stay pretty much the way it is. I don't see it as getting worse or better. It will just be changing to where you have more and more control, and individuals will be able to exert more and more control.

Q: Is the natural path of mankind out, or still on this planet?

A: There's nowhere else to go. (Laughter) Yes, we're the mammalian radiation you can still think of us as that. We're one of its prettiest little branches in terms of success, and that means expansion, and that means space. Unless we figure out something more interesting that doesn't require more space, and I just can't see that happening. I think we will require more space.

Q: It's really cheaper than living under the oceans, isn't it?

A: I think it's a lot more fun, too. I don't like being underwater that much. Being in space would be scary, too, in its own way, but once you have a large enough "thing" out there to live in, you have a whole lot more control over your environment than you have here, it will be in some cases ruthless almost, the things that people end up living in. But if you read these futurist writers that talk about what equipment that you will need—given that nobody's shooting at you, and you've got plenty of time to live out there, you have to have some space that's full of air. You've got to have some way to move that around or either to anchor it somewhere. And some way to get food. You can make food pretty easily. I make food up here. I don't make all of mine, but I could if I was willing to deal with a limited diet. I could support myself here. I could do it in some kind of a place if I had light, and I've got light from the sun. You have to have water. You have to have hydrogen, you have to have oxygen to make your water. You've got to have something to make your materials out of. Silicon will probably work fine.

Q: In terms of policy, what should this government then be planning for the Air Force? Should the Air Force become the executive agent for the United States Government in space?

A: I think it would be. That's a reasonable thing. The British Navy in the 18th Century did a fairly good job at that. You want to have your diplomatic contacts associated with some kind of military. It doesn't have to be ugly, but this feeling of being backed up by these guys when I'm going to be talking to people is a comfort.

I really think that asteroids are going to fall on the earth, too. Even if there aren't any other people out there. If you think about what our first serious contact with space might be, it might be some lifeless object that's five miles in diameter and is coming our way at 17,000 miles per

second, and it's going to destroy the planet in terms of life. We need to be able to deal with that. You need some kind of way to force that off of its course and move it. If people don't think that's going to happen, they should look at the surface of Mars and the moon, and say, "What made all those holes?"

Q: How about Tanguska?

A: That's recent. It is not something that happened in the past and won't happen again. Sixty-five million year ago it wiped out 99 percent of life on the planet, the thing that landed in Yucatan. Sixty-five million seems like an awful long time, but it doesn't take something like that to make a mess out of a society like ours. That is maybe our first need that we'll have for some kind of weapons, because weapons can be used against something like that to alter your course.

Q: What would be your recommendation? What kind of thing would you envision for that? A deflective blow or what?

A: Teller, I think, is thinking of nuclear things. I like a graviton laser. Something that you just point at it and it deflects it. That's the nicest way to do it. Tractor beams work, I think, in science fiction. Those are things people have to figure out how to make. If you can imagine it, somebody can make it eventually. But that kind of stuff fits real well with a force who's sort of orientation is weapons, that's force. You use force against something that's hurling toward you at a high velocity—whether it's got people in it or not, and most of them are not going to have people in them, they're going to be just asteroids kicked out of their orbit and they're heading towards the sun and they happen to hit the earth on the way.

Q: How about the moon as a launch base or as a base for that kind of watch?

A: The moon's a great place to get materials to launch them into orbits between the moon and the earth, to make things out of. It's hard to get stuff off the earth. The moon has got even one-sixth, even though it's farther away, it's got less gravity. The moon is a good place to be getting stuff, have a base there, an industrial base. The asteroids also are real nice handy sources of various elements that you'll need. I see us just expanding right on out. The asteroids will probably be a real interesting place in another 100 years. They'll be populated with all kinds of stuff—mining, manufacturing, and you need at least a police force, and the Air Force would probably be the logical choice for awhile.

Q: Are you an advocate of colonizing Mars?

A: I'd like to go find out what that "face" is, but I don't think Mars is all that great a place to be. If we're going to get out there, why land on another planet with gravity. Mars doesn't have air. It's got a tenth of a millibar or something like that. It's a very, very minuscule amount of air so you don't have that advantage. What are the advantages? There's no liquid water, it looks like. The moon would probably be a better place. It would be just as hostile, but easier to get on and off of.

Q: I've always said if you can go to the moon then Mars doesn't matter. You can live on the moon. You can go to the Mars if you want to. You can certainly survive there, you can survive on Mars.

A: I think we ought to go look at everything that NASA has photographed already that looks so intriguing. There's a lot of stuff up there that's not geological looking.

If you really start looking at it closely, you'll find this place has been inhabited and reinhabited and reinhabited for eons. There will be all kinds of stuff we'll find out there, and Mars is the first place. It looks like they've found something there. Nobody in a serious position wants to admit it, apparently, but they've definitely found some interesting archeological ruins on Mars. I feel like they'll probably find those all over the solar system. There will be signs of things, and every now and then there will the things themselves. I'll bet you there's probably relics, there's probably old cars laying around. (Laughter)

Q: Is this the best time you could have picked to be here, or can you think of another time you'd rather be here?

A: I like it right now. What you said reminds me of something I discovered recently. I got an Encyclopedia Britannica from 1894, and I looked up space. What do you think it said about space? It says, "Space: Ways of decorating the space, using the space in your house." Not a word about space as a place. Space is now a place, and it didn't use to be a place. Just 100 years, it's changed that completely. Now space in the Encyclopedia Britannica talks about space as a place, full of things that we are going to find. That's a real nice time to be here. Also, I'm kind of like Candid in Voltaire. I think this has got to be the best, this is where I am.

Q: This is the first generation that has ever photographed eight of the nine planets up close and in detail.

A: Yes. We're right on the edge. It is, in fact, happening right now. There are some of us up there right now, aren't there?

Q: How do you get the kids involved? How do you get them excited and involved in this thing?

A: The children, and when I say children now, I'm talking about 14 and 15 year olds. I sometimes think about 20 years olds too, and 25 year olds.

I think there's a definite need for them to have something that excites them. When I was in my early 20s we had the 1960s happening, and it made, for better or for worse, a lot of us really just took off from that. It gave us enthusiasm. All kinds of things opened for you. A lot of people didn't like some of them, but there was an enthusiasm associated with the '60s which picked up young people and drove them to all kinds of extremes.

I feel like when I talk to 14, 15 year old people now, they don't have that, so they've got a grim look. They have a feeling that times are just not conducive to open-ended development. There's a weird kind of a reaction to the enthusiastic freedom and optimism of the '60s. History

goes back and forth like Hegel said. We're in a phase now where we're pretty much at the bottom on the pendulum. Something will come along. It's like the properties of time in history of human things, there's no way to stop it from getting better. It will. But leaders right now should be thinking about what might help this process along. They might throw some germinating kind of stuff down into that very fertile ground that's going to swing back into a sort of enthusiastic period.

Q: Why? Because kids think it's all been done, or they feel that the leadership of this country and other countries is in no mood for further expansion? It seems we're shrinking and withdrawing.

A: They've heard "no" too often. It's been a "no" kind of a period, a very heavy, "No, don't do this. No, you can't do this. No, stay away from this. No, get off these." That kind of stuff. That has a cumulative effect on your psyche. "No, don't build anything, it messes up the environment. No, don't use anything because it wastes it." The "no" is going to get softer and softer, and the yes is going to come back as this sort of thing goes back and forth.

Q: They need possibilities.

A: They have them, they just need to look at them, to see them. They should be encouraged to explore them, and not looked at as a bunch of juvenile delinquents. They always are going to look like juvenile delinquents to an old person who's used to his ways. But we should encourage their juvenile delinquency, encourage them to be the youth and to say "Okay, what are you guys going to do?" Go ahead. It's a big world, and it's there. It's just like it was 100 years ago. It's more fun, actually, right now. But you're not a bad force in it. Your species is a hot little species, and it's a funny little "ape thing" and it's having a good time, and you ought to be doing that with it. You shouldn't be thinking of them as being awful marauders or something. We're not hurting this place. And if we do, let's go find another one somewhere. But I don't think we could hurt this place. We are this place, in a sense, and people ought to realize that. We're as important in it as the whales.

Q: How do you get them to think and use their imagination and apply it to what they see and go beyond that? How do you get people to do that?

A: I think you don't have to get them to do that. All you have to do is not step on them. Life is the sort of result of the promiscuous activity of a bunch of molecules. That, itself, is a creative thing. As long as you don't step on it, it will do all those things.

Q: Are we old guys stepping on them?

A: I think they're getting stepped on a lot. There's a very negative attitude that's been spawned by the excitement and the freedoms that were introduced back in the '60s. Suddenly everything that happened back there is thought of as bad—sex, drugs, rock and roll in particular. That's a natural thing that you can't avoid because every action reduces itself to a reaction. That's the way it works. For good or bad, that's how it works. You can't have a steady incremental change for a long time in the world. It just doesn't work that way. It's always back and forth.

We're in the back part of that sort of thing, and that's the birth of something else. I'm very hopeful about it because I think you look at history and you look at humans—as ugly as they are sometimes, they always show themselves to be a really neat thing to us. I don't think of them as bad. I think we will look, way off in the future looking back at the '90s, the next century we'll say wow, it was really neat what happened out of that repression. They bounced back up out of that. It was really neat. I don't think you have to actually intentionally encourage it. Just don't stop it. Listen to Bob Dylan.